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ANALYSIS OF VISUAL DETECTION PERFORMANCE
(FALL 1978 EXPERIMENT)

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N O T I C E

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This report is the first in a series which documents the Visual Search Effectiveness Task of the Probability of Detection in SAR project at the USCG R&D Center.

16. Abstract

From 11 September 1978 to 6 October 1978 a visual detection experiment was conducted in Block Island sound by the U.S. Coast Guard Research & Development Center. It was the first in a series of experiments designed to improve search planning guidance contained in the National Search and Rescue Manual.

This was a controlled experiment involving 82 and 95 foot cutters, 41 and 44 foot boats, helicopters, and fixed wing aircraft searching for white 16 foot boat targets anchored at predetermined locations within the search area.

Through the use of a microwave ranging system, the positions of searchers and targets could be accurately reconstructed to determine the lateral range of targets that were detected, as well as targets not detected. Thus, probability of detection versus lateral range curves could be developed, and, by integrating these curves, sweep width could be determined as well. A total of 695 detection opportunities were generated. A sophisticated binary multivariate logistic regression computer program was used to develop sweep width estimates for the environmental conditions experienced.

Of the eight visual detection parameters investigated, visibility, wind speed, swell height, cloud cover, search unit type, and duration of search were determined to have a significant effect on sweep width. The sweep width is an excellent measure of search unit performance. A more rapid degradation of sweep width was found for deteriorating environmental conditions than is now predicted by the National Search and Rescue Manual. ~~(continued)~~ over

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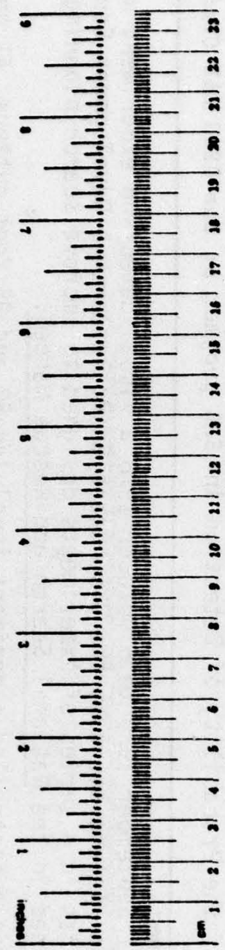
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

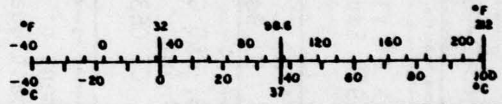
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



The methods used to conduct this experiment and analyze the data were found to be successful, and are recommended for future experiments. In order to provide comprehensive recommendations on changes to the National Search and Rescue Manual, additional similar experiments, with persons in the water, life rafts, 30 and 45 foot boats, should be conducted.

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EXECUTIVE SUMMARY

INTRODUCTION

This report is an analysis of a Coast Guard Research and Development (R&D) Center visual detection experiment conducted from 11 September 1978 to 6 October 1978. This was the first in a series of detection experiments designed to improve search planning guidance contained in the National Search and Rescue Manual (USCG, 1973). A description of the planning and conduct of this experiment is also provided, along with conclusions and recommendations for improving the quality and efficiency of future experiments.

Sweep width is the performance measure used by Search and Rescue (SAR) mission coordinators to plan SAR searches. Conceptually, sweep width defines the swath cut by a Search and Rescue Unit (SRU) inside which targets are assumed to be detected with certainty (and outside which it is assumed they remain undetected). This simplification of the concept of probability of detection provides a viable tool for planning SAR operations.

However, the need for a re-evaluation of the National Search and Rescue Manual (SAR Manual) sweep width tables has long been apparent, both from the standpoint of improving their accuracy, as well as determining whether additional parameters not previously considered may significantly influence sweep width. Thus, this series of experiments, will evaluate the search performance of SRUs in detecting persons in the water, life rafts, and various sizes of boats for a representative set of environmental conditions.

The types of SRUs evaluated in this initial experiment were 82/95 foot cutters, 41/44 foot boats, helicopters and fixed wing aircraft. The targets were white, 16 foot open boats set at anchor. The influence of the following parameters upon sweep width was investigated:

1. Search Speed
2. Visibility
3. Wind Speed

4. Swell Height
5. Cloud Cover
6. Elevation of Sun
7. Duration of Search
8. Search Unit Type

The controlled experiment was conducted in Block Island Sound with sufficient repetitions to ensure validity and accuracy of results. (A total of 695 detection opportunities were generated.) A relatively sophisticated logistic regression computer program was used to model the lateral range curves upon which sweep width estimates were based.

RESULTS

Cutter and 41/44 foot boat sweep widths were found to be sensitive to swell height, wind speed, cloud cover, search unit type and duration of search; whereas aircraft sweep widths were sensitive to visibility, wind speed, and search unit type.

Table 1 provides an overview of sweep width values for each SRU type corresponding to environmental conditions which ranged from excellent to poor. Estimates of sweep width are not provided for aircraft in a poor environment since no aircraft searches were conducted under these conditions.

CONCLUSIONS

The scientific method used for the conduct and analysis of this controlled experiment was successful in meeting the stated objectives. For the environmental conditions experienced during this experiment, the following specific conclusions can be drawn:

1. For fixed wing aircraft, an increase in search speed was found to reduce sweep width, while for cutters, boats, and helicopters an increase in search speed was <u>not</u> found to degrade search performance. Thus cutters, boats, and helicopters should search at the maximum speed that environmental

TABLE 1. COMPARISON OF AIRCRAFT AND SURFACE CRAFT SWEEP WIDTHS

UNIT TYPE	SWEEP WIDTH (nm)	ENVIRONMENTAL CONDITIONS			
		VISIBILITY (nm)	WIND SPEED (KNOTS)	CLOUD COVER (%)	SWELL HEIGHT (FEET)
		EXCELLENT CONDITIONS			
Helicopters	7.5	15	1	0	1
Fixed Wing Aircraft	5.9				
82'/95' Cutters	5.5				
41'/44' Boats	4.8				
		GOOD CONDITIONS			
82'/95' Cutters	3.8	10	10	0	2
41'/44' Boats	3.1				
Helicopters	3.2				
Fixed Wing Aircraft	1.9				
		FAIR CONDITIONS			
82'/95' Cutters	2.7	8	12	100	2
41'/44' Boats	2.1				
Helicopters	2.2				
Fixed Wing Aircraft	1.2				
		POOR CONDITIONS			
82'/95' Cutters	0.9	-	20	100	4
41'/44' Boats	0.6				
Helicopters	-				
Fixed Wing Aircraft	-				

Note: Surface craft mean search duration 2 hours. Helicopter mean search duration 45 minutes. Fixed wing aircraft mean search speed 150 knots.
Significant surface craft variables: wind speed; cloud cover; swell height; search duration; search unit type.
Significant airborne craft variables: visibility; wind speed; search unit type.

conditions will permit. This will minimize the time required to search a particular area with a given probability of detection.

2. Surface craft search performance degraded more rapidly as environmental conditions deteriorated than is predicted by the SAR Manual. (Aircraft did not search under as wide a range of environmental conditions as surface craft. Thus, while a similar conclusion could not be drawn concerning aircraft search performance, there is no assurance that such an effect does not exist.)

3. The degradation of surface craft and helicopter performance over the course of a search was significant. For surface craft under marginal conditions (20 knots wind speed and 4 feet swells) after four hours of search, sweep width was reduced by as much as 43 percent. Helicopters exhibited a similar reduction in performance over a two hour search. This dramatic reduction in sweep width as a search progresses underscores the necessity for understanding the human factors that contribute to this reduction so that the effects can, if possible, be reduced.

4. Sweep width was found to continually decrease as wind speed increased from 1 to 25 knots. These results are in conflict with the SAR Manual sweep width tables that predict an increase in sweep width as wind speed increases from 0 to 10 knots, followed by a continued decrease in sweep width as wind speed increases above 10 knots. The SAR Manual explains the increase in sweep width as wind speed goes from 0 to 10 knots by predicting that "with small targets on glassy seas...difficulty will be experienced in detection due to the reflections of sun, sky, and clouds on the sea surface." However, these particular environmental conditions seem relatively unlikely. Thus representing the influence of wind speed on sweep width as a monotonically decreasing function seems, by preliminary assessment, to be more appropriate. Subsequent experiments should serve to either substantiate or disprove this hypothesis.

5. The type of search unit was found to be a significant parameter in determining sweep width. Cutters performed better than SAR boats, and helicopters outperformed fixed wing aircraft. The sweep width tables of the

SAR Manual give only one sweep width for surface vessel search and one for each of three altitudes of aircraft search under any set of environmental conditions. The sweep width tables predict increasing performance with altitude up to 2000 feet. Since there are performance differences between such unit types, a distinction should be made in the sweep width model. An evaluation of the effects of altitude on detection are warranted since the fixed wing aircraft flying at a higher altitude did not perform as well as helicopters.

6. For surface craft, under the most extreme environmental conditions experienced during the experiment (wind speed of approximately 20 knots, 4 to 5 feet swells and 100 percent cloud cover) the estimated probability of detection for targets that passed close aboard (near zero lateral range) was as low as 32 percent. For the most extreme environmental conditions experienced by aircraft (8 nautical mile meteorological visibility and wind speed of 12 knots) the probability of detection for contacts that passed close aboard was as low as 45 percent. Since the relatively low probabilities of detection may not be consistent with the probability of detection versus coverage factor curves of the SAR Manual, a comparison would be warranted to ensure that the probability of detection estimates derived from this figure are accurate over a range of environmental conditions.

7. While the amount of data collected with a 16 foot boat target provided a good deal of confidence about the validity of the results, the limited range of environmental conditions experienced restricts application of these results. In order to allow more general use of results, detection data should be collected for the following additional conditions:

1. Low meteorological visibility (5 nautical miles or less)

2. Wind speed greater than 15 knots and swell height 3 feet or greater (aircraft only)

3. First/last light searches (elevation of sun less than 30 degrees)

4. Overcast days (aircraft only).

RECOMMENDATIONS

In order to make comprehensive recommendations on changes to the National Search and Rescue Manual visual sweep width tables, additional experiments each of 5 to 6 weeks in duration should be conducted with the following types of SAR targets:

1. Persons in the water (PIW)
2. Life rafts
3. 30 foot boats
4. 45 foot boats.

The experiments should be conducted over a wide range of environmental conditions so that the results have general application. A data base of 450 observations each for surface craft and aircraft should be collected for each target type to determine parameter significance and estimate the sensitivity of sweep to changes in these significant variables.

CHAPTER 1
INTRODUCTION

1.0 SCOPE

This report describes the planning, conduct, and analysis of a Coast Guard Research and Development (R&D) Center visual detection experiment conducted from 11 September 1978 to 6 October 1978. This was the first in a series of experiments designed to quantify Search and Rescue Unit (SRU) performance, and to improve upon the search planning guidance provided by the sweep width tables of the National Search and Rescue Manual (SAR Manual). This report also recommends changes in future experiment design and conduct that should improve the efficiency and accuracy of data collection efforts.

1.1 Background

A key ingredient to effective Search and Rescue (SAR) planning is an accurate understanding of the capabilities of various SRUs for conditions existing in the search area. Overestimating search unit performance may result in premature termination of the search of a particular area, while underestimating search unit performance may result in the search of a particular area to be extended unnecessarily (thereby delaying search of other areas). In either case, SAR resources would not be utilized in an efficient manner.

1.2 Sweep Width

The performance measure utilized by SAR mission coordinators to plan searches is sweep width (W). Sweep width is a single number summation of a more complex range detection probability relationship. Mathematically,

$$\text{Sweep Width (W)} = \int_{-\infty}^{\infty} p(x)dx,$$

where

x = lateral range (see Figure 1-1) and

$p(x)$ = probability of detection at lateral range x.

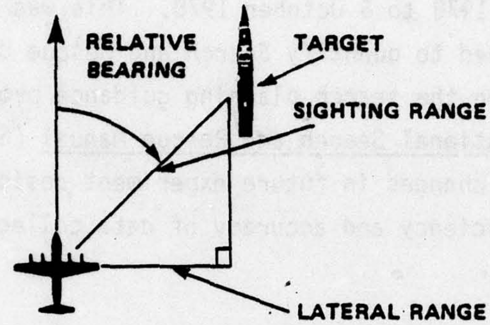


FIGURE 1-1. DEFINITION OF LATERAL RANGE

Figure 1-2 shows a typical probability of detection curve as a function of lateral range. In Figure 1-2, R_D is the lateral detection or missed range.

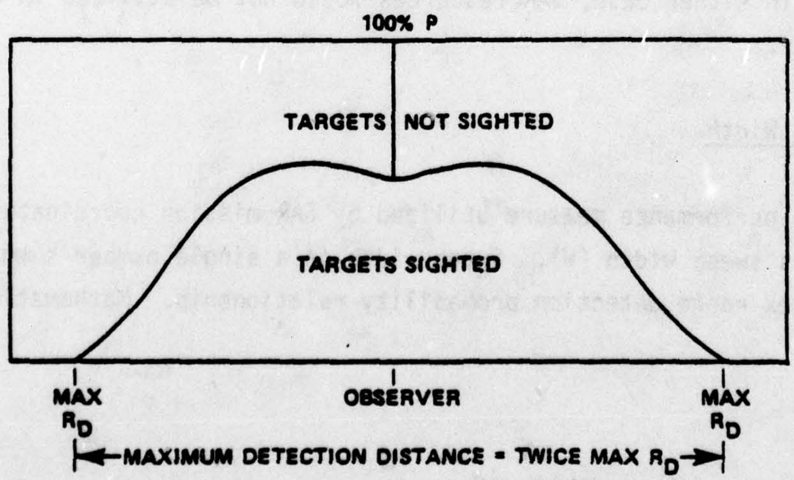


FIGURE 1-2. RELATIONSHIP OF TARGETS SIGHTED TO TARGETS NOT SIGHTED

Conceptually, sweep width is the numerical value obtained by reducing the maximum detection distance of any given sweep so that scattered targets which may be detected beyond the limits of W are equal in number to those which may be missed within those limits. Figure 1-3, (A and B) graphically presents this concept of sweep width. The number of targets missed inside the sweep width distance is indicated by the shaded portion near the top middle of the rectangle (area A) while the number of targets sighted beyond the sweep width distance is indicated by the shaded portion at each end of the rectangle (area B). Referring only to the shaded areas, when the number of targets missed equals the number of targets sighted, (area A = area B) sweep width is defined. A detailed mathematical development and explanation of sweep width can be found in Search and Screening (Koopman, 1946).

1.3 Parameters

From literature research, twenty four parameters have been identified as having a potential influence on p(x) (probability of detection as a function of lateral range) and thus on sweep width. These parameters can be divided into three categories:

1. Primary independent measurable parameters (11 parameters)
2. Interdependent human factors (7 parameters) and
3. Secondary parameters (6 parameters).

1.3.1 Primary Variables

Primary Variables are those intended to be investigated during the planned series of experiments. They are:

1. Search unit type*
2. Target type and size
3. Visibility*
4. Altitude
5. Search speed*

*An asterisk identifies those parameters investigated during the experiment described in this report.

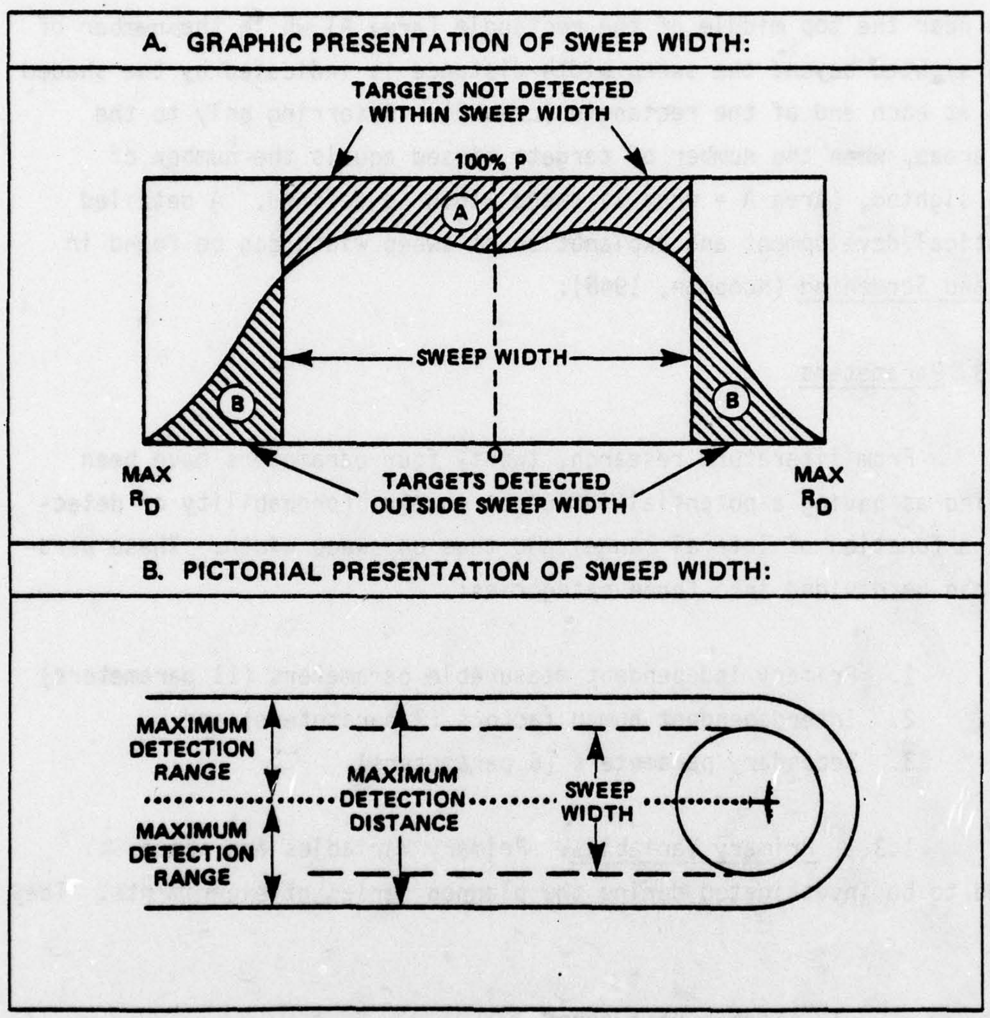


Figure 1-3. GRAPHIC AND PICTORIAL PRESENTATION OF SWEEP WIDTH

6. Search duration*
7. Target and background contrast
8. Wind speed*
9. Sun's elevation*
10. Swell height*
11. Cloud cover.*

1.3.2 Interdependent Human Factors. Quality lookout performance is essential for the success of a visual search mission. The human factor effects are being studied separately by investigating lookout performance. This study assumes that the visual sensor (lookout) is only a part of the overall detection capability of the search unit. These factors, which are dependent upon type of search unit, duration of search, wind, sea state, and Coast Guard policies, are:

1. Fatigue
2. Stress (noise, glare, vibration, temperature, motion, etc.)
3. Visual acuity and perception
4. Training level
5. Experience level
6. Motivation level
7. Position of lookouts.

1.3.3 Secondary Parameters. The six remaining variables are either a function of the search unit type, search incident, or are continually changing during the search operation. The parameters under consideration, but not as primary independent variables, are:

1. Number of lookouts
2. Target movement and aspect
3. Relative wind direction
4. Sun's relative bearing
5. Lookout briefings
6. Visual aids.

---

*An asterisk identifies those parameters investigated during the experiment described in this report.

Few investigators have collected visual search data, and the tests conducted have omitted potentially significant sweep width variables. Of the 24 variables listed above, only 5 are used at present and the magnitude of their influence is uncertain. Thus, World War II visual search techniques, which have been updated once from sighting report data collected 23 years ago (Richardson, 1968), are utilized in SAR planning. Richardson's evaluation which updated the SAR Manual (USCG, 1973) sweep width tables, did not include such essentials as search unit speed, duration of search, and target-missed information, and no data was evaluated from surface search units. Also, Richardson's data was not gathered during a controlled experiment but was obtained from sighting reports of various Coast Guard operational missions and exercises. Finally, the sweep width tables of the SAR Manual do not include persons in the water, and all target boats 30 feet or less in length are lumped into one category.

1.4 Summary

The need for a re-evaluation of the SAR Manual sweep width tables is apparent, both from the standpoint of improving the accuracy of the present tables, as well as determining whether additional parameters not considered in the development of these tables may have a significant influence on sweep width. Thus, this series of experiments will determine those environmental, search unit and target characteristics which influence the search performance of boats, cutters, helicopters, and fixed wing aircraft in detecting persons in the water, life rafts, and various sizes of boats. Using the significant parameters, a statistically sound visual detection model will be developed from data collected. The experiment described in this report focused on the performance of these search units in detecting a single target type (a white, 16 foot open boat).

1.5 Scope of Effort

This section presents a guide for conducting similar experiments so that planners may better estimate the schedule and resource

requirements for such an effort. Planning began eight months before the experiment, while reconstruction, analysis and report preparation continued for three months after completion of the experiment. Figure 1-4 shows, chronologically, the tasks associated with the experiment. In the following sections, each task and its associated level of effort is described.

1.6 Tasks

1.6.1 Pre-Experiment Planning and Analysis. Included in this task were the following:

1. Identification of experiment objectives

2. Determination of data collection requirements and methods

3. Identification and acquisition of necessary resources

4. Analysis of a one day prototype exercise

5. Analysis of prototype exercise data, including modification to the regression analysis computer program

6. Estimating experiment sample size requirements based upon prototype exercise results

7. Estimating the amount of data the experiment would provide.

A total of 10.1 man-months were devoted to this effort.

1.6.2 Prototype Exercise. A one day exercise was conducted during the month of June in a 5 by 10 nautical mile area in Long Island

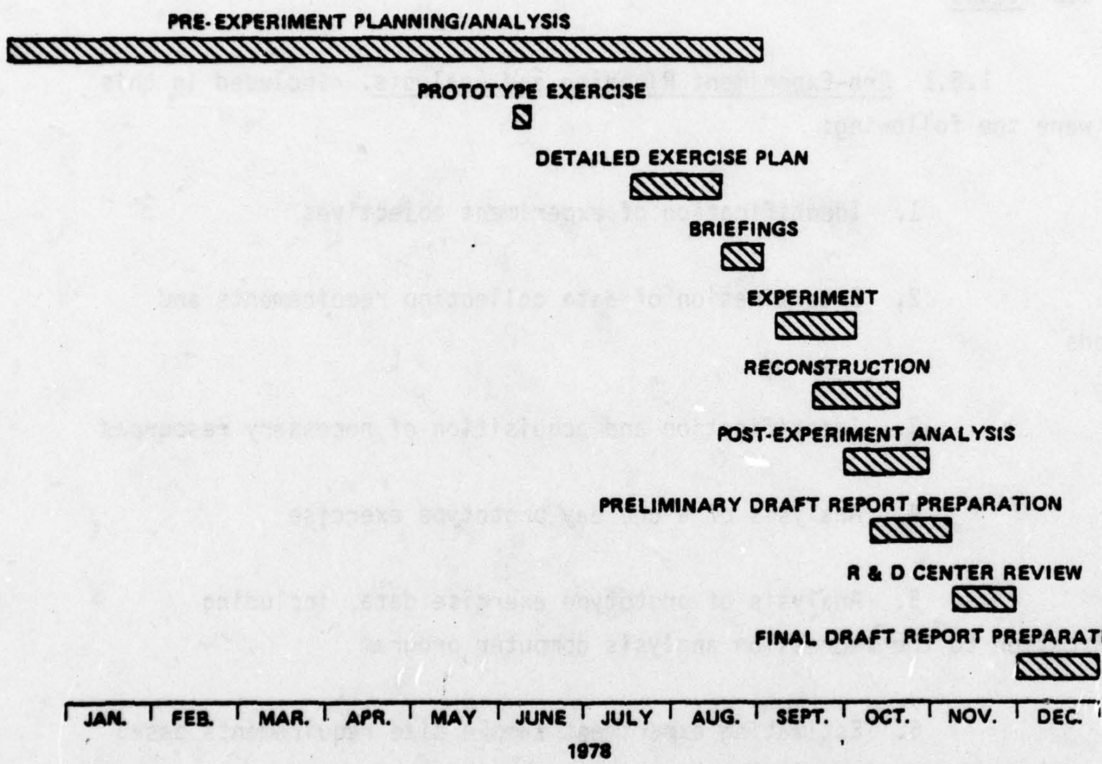


FIGURE 1-4. SCOPE OF EFFORT

Sound to gather preliminary data, evaluate data collection methods, and determine reconstruction requirements. Eight targets configured to simulate a person in the water were distributed in the area. Three SRUs (82 foot cutter, 95 foot cutter, and 41 foot utility boat) each conducted a creeping line search of the area with a 0.5 nautical mile track spacing. Reconstruction of the search tracks and target positions provided valuable insights in the necessity for an accurate measurement of these parameters. The exercise data was used as an input to the regression analysis program, and thus provided the means to estimate sample size requirements for the experiment. Approximately 0.4 man-months were devoted to this effort by R&D center personnel, and an additional 1.4 man-months by the three SRUs.

1.6.3 Detailed Experiment Plan. This document provided the exercise participants and observers with the following:

1. Background information

2. General instructions, including scheduling, run conduct, and descriptions of special equipment

3. Special instructions for each type of participant.

A total of 1.7 man-months were devoted to this effort.

1.6.4 Experiment Conduct. The experiment was conducted on fourteen days from 11 September 1978 to 6 October 1978. As many as four search units participated on each day. A total of 12.5 man-months from operational units were committed to this experiment. A total of 8.9 man-months were required of R&D Center personnel in functions including:

1. On-scene commander
2. Target placement and retrieval
3. Observers
4. Microwave Ranging System operators.

1.6.5 Reconstruction. A total of 2.0 man-months were required to reconstruct the searcher tracks and target positions. The majority of the track and target positions were reconstructed through the use of a Microwave Ranging System (MRS) and a Hewlett Packard 9845 desktop calculator, and X-Y plotter. The remainder of the experiment was manually reconstructed (see Section 2.3 for details).

1.6.6 Post-Experiment Analysis. A total of 5.4 man-months and 172 hours of computer time were required to analyze the experiment data and prepare this report.

1.6.7 Total Level of Effort. Listed below is the total effort involved in the planning, conduct, and analysis of this experiment:

1. R&D Center Personnel - 28.5 man-months
2. Operational Units - 13.9 man-months
3. Analysis Equipment:
   a. Computer (NOVA 840) - 252 hours
   b. Desktop Calculator (HP 9845) - 128 hours

Chapter 2 describes, in detail, the experiment and analytical approach.

CHAPTER 2
THE EXPERIMENT

2.0 GENERAL DESCRIPTION

2.1 Visual Detection Experiment

Numerous surface vessels and aircraft participated in the visual detection experiment conducted in Block Island Sound. A brief description of the characteristics of each type SRU and a list of the individual participants is given in Tables 2-1 and 2-2.

The search area was controlled, depending upon environmental conditions and was varied from a minimum of 205 square kilometers (60 square nautical miles) to a maximum of 1030 square kilometers (300 square nautical miles). The center of the search area, the direction of its major axis, and the area size are shown in Figure 2-1.

When using aircraft, in order to avoid high density boating areas such as Montauk Point and the Race, the center of the search area was shifted 1.8 kilometers (1 nautical mile) to the north and 1.5 kilometers (.8 nautical miles) to the east.

The entire experiment was conducted from 11 September 1978 to 6 October 1978. Originally it was planned to utilize seventeen days to conduct the experiment. However, due to adverse weather conditions, which made it impossible to place targets, two days had to be cancelled; due to MRS equipment problems, the experiment commenced a week late and was cancelled on one other day.

In order to make maximum use of resources (aircraft required a much lower target density than surface craft because of higher search speeds), surface craft and aircraft were scheduled on alternate days. It was planned that four surface SRUs (two cutters and two boats) would conduct searches on given days; on alternate days, it was planned to utilize two helicopters (HH-3F and HH-52A), and two fixed wing aircraft (HC-130 and HU-16E).

TABLE 2-1. SEARCH UNIT CHARACTERISTICS

SRU TYPE	CREW SIZE	MAX SPEED (KNOTS)	NAVIGATION EQUIPMENT	HEIGHT OF EYE (FEET)
SAR BOATS				
41 ft	3	20	DF+, Radar, Fathometer	10
44 ft	3	10	DF+, Radar, Fathometer	10
CUTTERS				
82 ft	8	18	LORAN A or C, Radar, DF+, Fathometer	25
95 ft	12	15	LORAN A or C, Radar, DF+, Fathometer	20
HELICOPTERS				
HH-52A	3	90	TACAN	--
HH-3F	4	115	TACAN, LORAN A, INS,* Radar	--
FIXED WING AIRCRAFT				
HU-16E	5	145	TACAN, Radar, LORAN A	--
HC-130	9	300	TACAN, Radar, LORAN A, INS*	--

*INS = Inertial Navigation System.
+ DF = Direction Finder.

TABLE 2-2. PARTICIPATING UNITS/FACILITIES

PROTOTYPE EXERCISE:

CGC Cape Fair Weather (WPB 95314), New London, CT
CGC Point Knoll (WPB 82367), New London, CT

CG Station New Haven, CT: CG 41309

EXERCISE:

CG Light Station Montauk, NY
CG Light Station Race Rock, New London, CT
CG Air Station Elizabeth City, NC: CG 1340, CG 1347 (HC 130B)
CG Air Station Brooklyn, NY: CG 1442, CG 1368, CG 1424, CG 1391 (HH 52A)
CG Air Station Cape Cod, Otis AFB, MA: CG 1473 (HH 3F); CG 7254, CG 7250, CG 1293 (HU 16E)

CGC Cape Horn (WPB 95322), Woods Hole, MA
CGC Cape George (WPB 95306), New Bedford, MA
CGC Point Bonita (WPB 82347), Woods Hole, MA
CGC Point Knoll (WPB 82367), New London, CT
CGC Point Turner (WPB 82365), Newport, RI
CGC Point Jackson (WPB 82378), Woods Hole, MA
CGC Point Wells (WPB 82343), Montauk, NY

CG Station New London, CT: CG 41413
CG Station Point Judith, Narragansett, RI: CG 41385, CG 44352
CG Station Montauk, NY: CG 41342, CG 44348
CG Station Block Island, RI: CG 41441, CG 44349

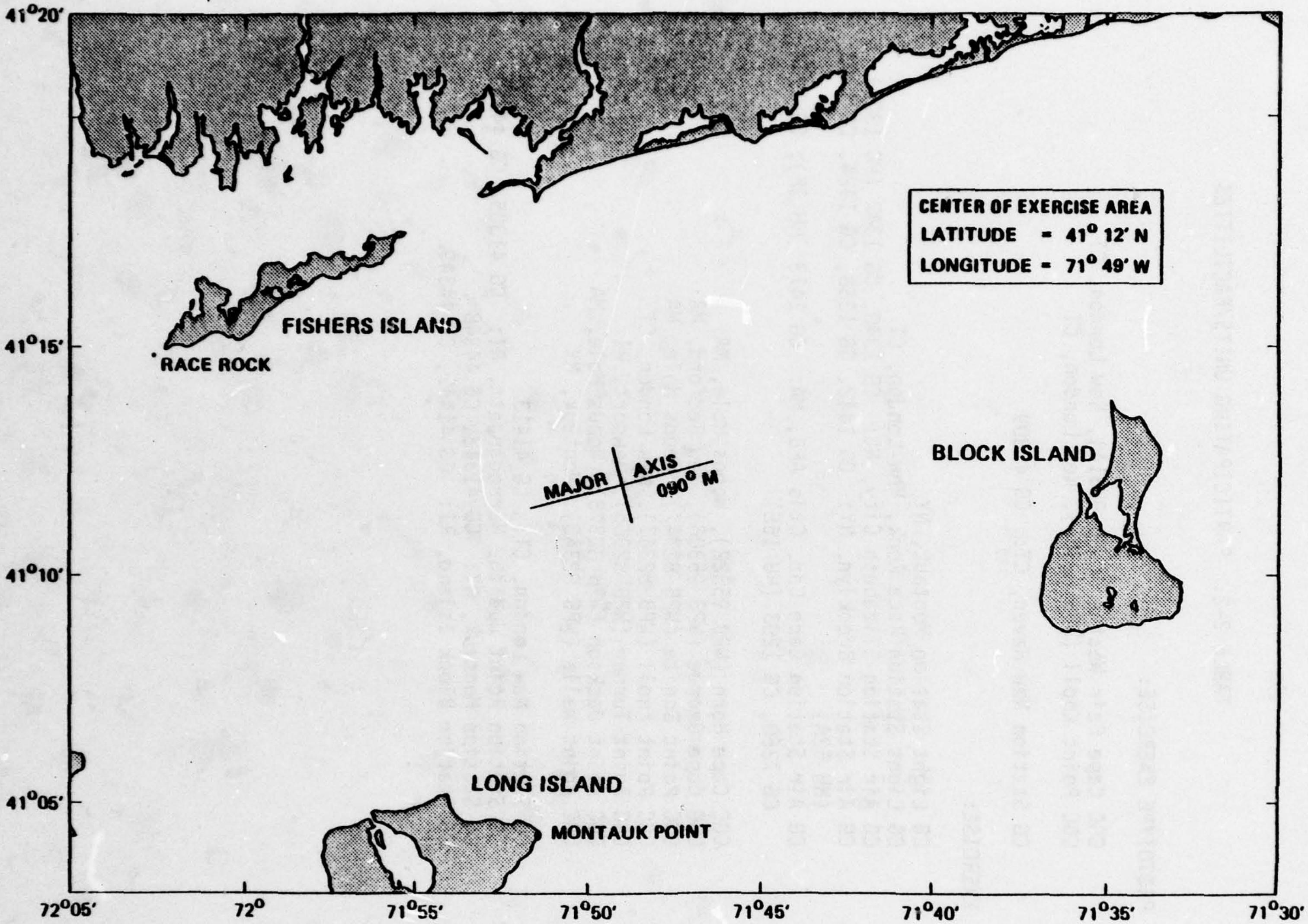


FIGURE 2-1. SEARCH AREA

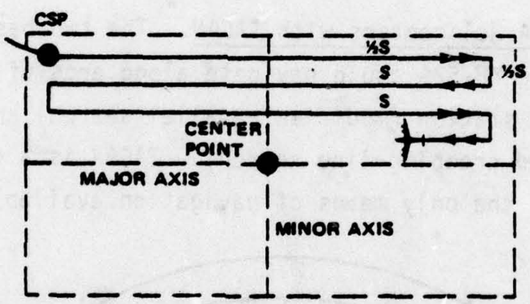
Appropriate time separation between surface units and altitude separation between helicopters and fixed wing aircraft were provided. Because of equipment failure, actual SAR missions, and other commitments, not all of the search units were available on some days during the experiment.

2.2 Search Tracks and Target Placement

Search unit tracks were laid out in the same manner as they would be for actual SAR missions. Two basic search patterns (see sketches below) were utilized: parallel and creeping line search (USCG, 1973).

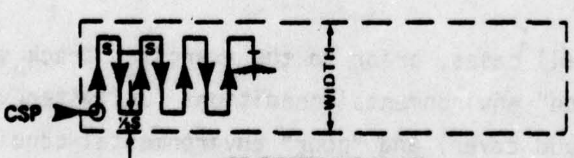
2.2.1 Parallel Search.

Search legs were parallel to the direction of the major axis of the search area and were separated by a specified track spacing. Commence start points (CSP) and outer search legs were one-half the track spacing (S) inside the perimeter of the search area.



2.2.2 Creeping Line Search.

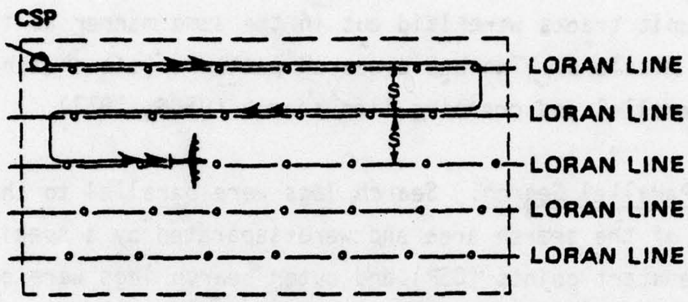
Search legs were perpendicular to the direction of the major axis of the search area and were separated by a specified track spacing. Start points and outer search legs were one-half the track spacing inside the perimeter of the search area.



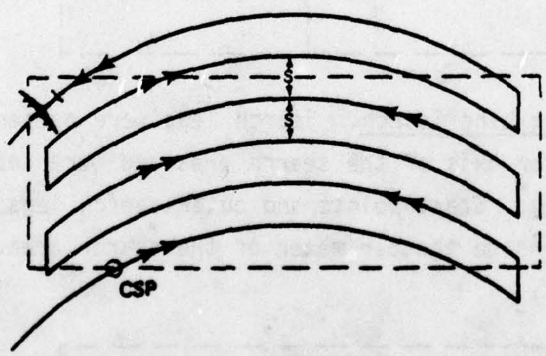
CS RECTANGULAR

In order to make best use of onboard navigational equipment (see sketches below), some units slightly altered the basic patterns.

2.2.3 Cutters with LORAN C (HU 16E with LORAN A). The two basic search patterns were skewed with respect to the major axis so that the cutters could follow LORAN C lines, and the HU-16E could follow LORAN A lines.



2.2.4 HH-52A Helicopters with TACAN. The two basic search patterns were skewed so that the HH-52A could navigate along arcs of constant range from the Norwich TACAN station (modified parallel search) and from the Hampton TACAN station (modified creeping line search). TACAN is a distance measuring navigation net and was the only means of navigation available for an HH-52A search.



In all cases, prior to the exercise, track spacing had been estimated for "good" environmental conditions (unlimited visibility, low wind speed, low cloud cover) and "poor" environmental conditions (low visibility, high wind speed, high cloud cover). When appropriate, changes in track spacing were made by the On-Scene Commander (OSC). Track spacing of 4-5 miles was used for good conditions, and track spacing of 2 miles was

used for poor conditions. Targets (16 foot open white boats with about 3 feet of free board) were positioned at predetermined locations by the monitoring vessel (42 foot UTB). Each day, a microwave ranging system was utilized to accurately determine the initial location of anchored targets. Additionally, at the end of each search day, target locations were again checked to ensure that the targets had remained stationary.

The number and positions of the targets relative to planned search tracks were designed to provide about six detection opportunities per hour. This number was a compromise between the desire to obtain as much data as possible in a given time interval and not biasing the results of the experiment by overloading the lookouts.

When possible, searches were conducted in the same manner as actual SAR missions. Twenty-four hours prior to each search, the CG R&D Center released a SAREX (SAR exercise) message to each search unit providing it with the detailed information necessary to conduct the desired visual searches. Each morning, targets were towed to the search area and positioned by the 42 foot UTB (which also served as a command post for the OSC). After the targets were positioned, the searchers proceeded to designated start positions and initiated search procedures as described in the SAREX message. Each of the search units had at least one observer on board. It was the observer's task to record sighting information, ensure that the search plan was being adhered to (e.g., see that searchers did not deviate from the search track to classify a sighting or did not go through the search area before or between search runs), note any artificial influences which might bias the test results, and record any suggestions for improving the experiment.

Each day, visibility, wave height, wind speed, and cloud cover were recorded at hourly intervals by the OSC and observers.

For each target sighting, the following data were collected by the observer onboard each search unit:

1. Time target was sighted
2. Approximate range and relative bearing to target
3. Relative bearing of sun
4. Searcher course, speed, and altitude
5. Contrast of the target with the background
6. Position of lookout making sighting

Special equipment used during the exercise included a Microwave Ranging System (MRS) (see Section 2.3) and a hand held anemometer which provided wind speed and direction data.* Also, one of the two HC-130 aircraft employed as an SRU during this experiment was configured as part of the Airborne Oil Surveillance System (AOSS) with a Side Looking Airborne Radar (SLAR). SLAR was operated throughout the HC-130 aircraft searches to:

1. Provide an aid in reconstructing the units track (the HC-130 was not equipped with a MRS responder),

2. Provide preliminary data as to the utility of SLAR as a SAR sensor.

SLAR has maximum theoretical detection ranges of 13.5 and 27 nautical miles. The operator station provides real time video displays of the sensor data in "rolling map" format.

2.3 Reconstruction

Throughout the experiment, a microwave range measurement system was used to locate the position of search units and targets. A master transmitting unit was located at Race Rock Light Station and a secondary transmitting unit was located at Montauk Point Light Station. Each mobile unit was also equipped with a responder to re-transmit received signals. Figure 2-2 shows Race Rock, Montauk Point and a typical SRU location.

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*The AN/PMQ-3 anemometer contains a small cylindrical turbine wired to a generator which produces a voltage proportional to the wind speed. Wind speed indications are accurate to within one knot in the range 0 to 10 knots and 1½ knots in the range 11-40 knots.

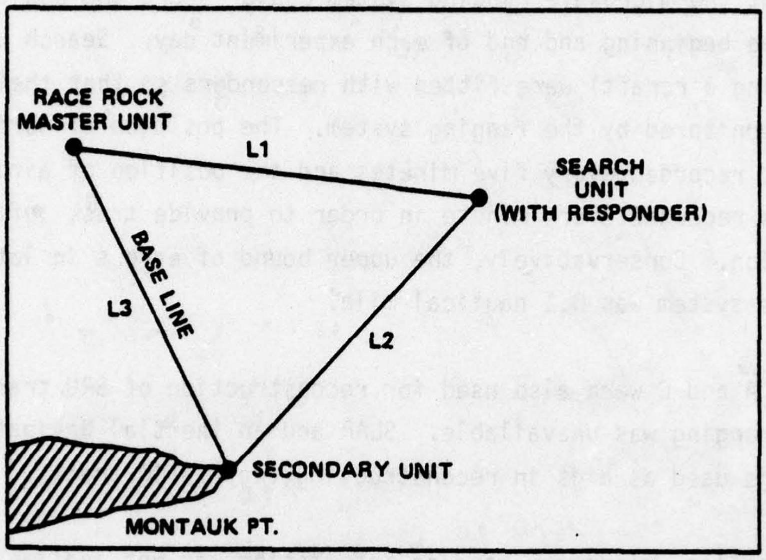


FIGURE 2-2. MICROWAVE RANGING SYSTEM OPERATION

The system functioned as follows:

1. The master unit transmitted a pulse at 5400-5600 MHz which triggered the responder on a particular mobile unit.

2. The responder in turn transmitted a pulse which triggered the secondary unit at Montauk Point and was also received at the master unit on Race Rock.

3. The secondary unit on Montauk Point transmitted a pulse which was received back at Race Rock.

The master unit measured two time delays: one corresponding to twice the distance from Race Rock to the responder (L_1), and one corresponding to the loop range ($L_1+L_2+L_3$). The output of the master unit was a hard copy of time, distance from Race Rock to the SRU, and one-half loop range. Range accuracies with the system were ±3 meters.

The monitor boat, which positioned targets, was fitted with a responder so that the microwave ranging system could record the position of targets at the beginning and end of each experiment day. Search units (except fixed wing aircraft) were fitted with responders so that their positions could be monitored by the ranging system. The position of surface search units was recorded every five minutes and the position of aircraft search units was recorded every minute in order to provide track information for reconstruction. Conservatively, the upper bound of errors in lateral range using this system was 0.1 nautical mile.

LORAN A and C were also used for reconstruction of SRU tracks when microwave ranging was unavailable. SLAR and an Inertial Navigation System (INS) were used as aids in reconstructing the HC-130 tracks.

On occasion, microwave ranging information was not available and the analyst used manual reconstruction when good navigation information was available. When navigation information was less accurate than 0.1 nm, the data was not included in the analysis. Manual reconstruction relied upon LORAN A, LORAN C, visual and radar fixes, SLAR recordings, INS positions, and dead reckoning. In some instances, the microwave ranging system provided time and direct range from Race Rock to the SRU but did not provide half loop range. In these situations, the SRU could be located at successive times on arcs of circles centered at Race Rock. Knowing the speed and desired track of the SRU, its track across these arcs could be reconstructed. Thus, for manual reconstruction, it is felt that representative accuracies in lateral range were also 0.1 nautical mile.

2.4 Data Collection Techniques and Data Accuracy

Each SRU had at least one observer onboard at all times during the experiment. The major responsibility of the observer was to record all pertinent data for each target sighting, the time of day, estimated target range, and estimated relative bearing of the target were of critical importance. (Sighting time, relative bearing, and range estimates of targets were the prime parameters used to decide whether a sighting was a valid detection.)

Accordingly, all SRU's synchronized watches with the OSC at commencement of the first search. This was especially critical for high speed search aircraft.

A daily record of all environmental data was maintained by the OSC. Wind speed and direction were recorded using a hand-held anemometer. Wave height (swell), cloud cover, and visibility were estimated by the OSC and by the observer on each SRU.

2.5 Experiment Design Considerations

2.5.1 Pre-Experiment Estimation of Sample Size Requirements. Coast Guard SAR planners generally choose a track spacing equal to the best estimate of sweep width (i.e., a coverage factor of one). Coverage factor (C) is a measure of search quality and is equivalent to sweep width (W) divided by track spacing (S). To determine the experimental criterion, an arbitrary cumulative search probability of detection (POD) for three uniform searches was chosen, since repeated searches raise the POD to an acceptable level. Assuming that the search craft precisely navigate the search pattern, Figure 2-3 (USCG, 1973) implies an estimated 98 percent POD after three searches using a coverage factor of 1.0. However, due to differences between the types of search platforms, the level of fatigue, and the inaccuracies in estimating environmental conditions, the coverage factor estimate will not always be correct for the search conditions. For all practical purposes, a random search curve can be used to form the lower bound for POD (McCullough, 1969), which is 95 percent after three uniform searches. In order to place an acceptable lower bound on the sweep width estimates resulting from this experiment, the following criterion was thus established:

> "After three uniform searches of an area with a coverage factor of 1.0, the expected probability of detection is 98 percent. Assuming a constant track spacing, the errors in sweep width estimates predicted for this experiment should result in an actual POD after three searches of no less than 95 percent (with a 95 percent confidence)."

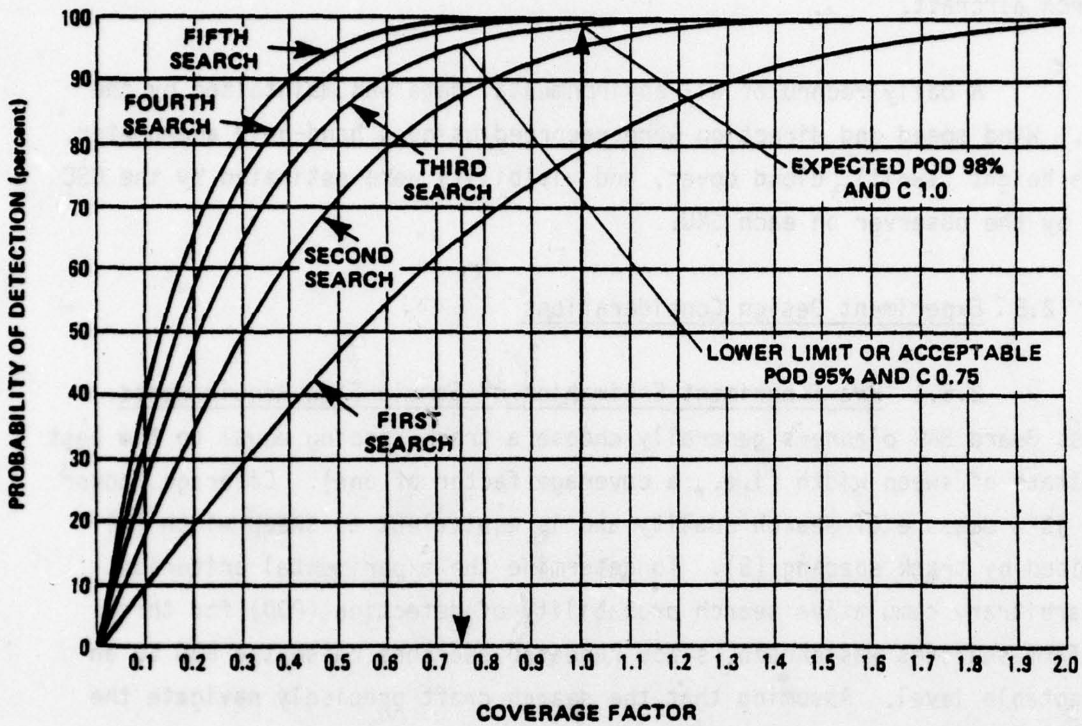


FIGURE 2-3. PROBABILITY OF DETECTION

From Figure 2-3, the 95 percent POD after three searches corresponds to a coverage factor of 0.75. Since track spacing remains constant, sweep width varies directly with coverage factor in $C = \frac{W}{S}$. Therefore, the lower bound on the 95 percent (single tail) confidence interval must be 0.75 of the sweep width estimate. Thus, the maximum allowable percent error in sweep width is 25 percent.

This criterion was related to a required number of detection opportunities for a single set of conditions by analysis conducted of the June 1978 prototype exercise. From the SAREX, it was determined that the errors in sweep width were normally distributed. Thus, an acceptable standard error to meet the criterion above could be determined. A 95 percent confidence interval for a single sided test implies that the confidence interval would

be 1.65 standard errors from the sweep width estimate. There was a standard deviation associated with a sample inversely related to the square root of the sample size. Analysis of this data indicated that a minimum of about 60 detection opportunities for a particular set of conditions were necessary to meet the above criterion.

This information was used in the experiment design to determine those controllable variables that should be allowed to vary and those that should remain constant. For example, because of a limited availability of aircraft detection opportunities, it was decided to maintain aircraft altitude constant throughout the experiment, rather than attempt to evaluate the influences of changes in altitude on POD. Also, the targets used were limited to one type, color and size. Therefore, the target to background contrasts were not evaluated.

2.5.2 Replication and Randomization. On each day of the experiment, up to four SRUs searched simultaneoulsly and provided a number of replications for each set of environmental conditions encountered. Boats and cutters searched simultaneously on each surface craft search day, and both helicopters and fixed wing aircraft searched simultaneously on each aircraft search day. This provided data for a direct comparison of different type search units under the same environmental conditions. All units were provided with the same information and similar search instructions so as not to bias exercise results in favor of any particular type SRU. Controllable factors such as search speed and search pattern (parallel search or creeping line search) were randomized in order to minimize bias due to unknown or unmeasureable factors. For example, to minimize the chance that any changes in performance attributed to change in search speed would be caused by a change in some unknown factor, each SRU was assigned a high speed for one search and low speed for the other. The order in which these speeds were assigned was alternated between successive units. Additionally, search patterns were almost always changed between consecutive searches. Thus, a variety of search speeds for each pattern was attained. Aircraft and boat crews were generally changed on successive days so that performance would be indicative of SRU type rather than a specified crew.

2.6 Description of Experiment Conditions

2.6.1 Summary of Detection Opportunities/Search Speeds. Table 2-3 provides a summary of the total SRU resources dedicated to this experiment. The total number of detection opportunities and the percentage of time spent at each of several search speeds, is also given for each type of search unit.

2.6.2 Range of Environmental Parameters. The range and distribution of environmental parameters during the experiment are displayed in Figures 2-4 and 2-5.

Figure 2-4 demonstrates the correlation of wind speed and swell height, and the tendency towards correlation of increased cloud cover and high (greater than 3 feet) swell height. Figure 2-5 shows little correlation between visibility and percentage of cloud cover. It does indicate that there was a low percentage of cloud cover during most of the experiment.

2.7 Analysis Approach

2.7.1 General. The primary objective of this analysis was to determine the significance of the independent variables and to develop sweep width estimates for each class of SRU (cutters, boats, helicopters and fixed wing aircraft). Searches were conducted for 16 foot boats at various search speeds under a variety of environmental conditions. Since sweep width is a single number representation of a more complex lateral range/probability of detection relationship, the key task of the analysis was to develop probability of detection versus lateral range curves that accurately represent the characteristics of the experiment data. Experience has indicated that data of this type generally exhibits the classic stimulus-response (S-R) curve shown below.

TABLE 2-3. SUMMARY OF SRU RESOURCES

SEARCH UNIT TYPE	NUMBER OF UNITS	TOTAL SEARCH TIME (HOURS)	TOTAL SORTIE TIME (HOURS)	TOTAL NUMBER OF DETECTION OPPORTUNITIES	SEARCH SPEEDS (KNOTS)	SEARCH TIME (%)
BOATS	7	51.4	92.9	173	8 10 15 20	14 67 4 15
CUTTERS	7	59.9	134.1	247	8 10 12 15 17	19 12 28 35 6
HELICOPTERS	5	19.7	50.5	146	60 85 120	31 65 4
FIXED WING AIRCRAFT	5	12.6	70.8	129	120 150 200	25 65 10

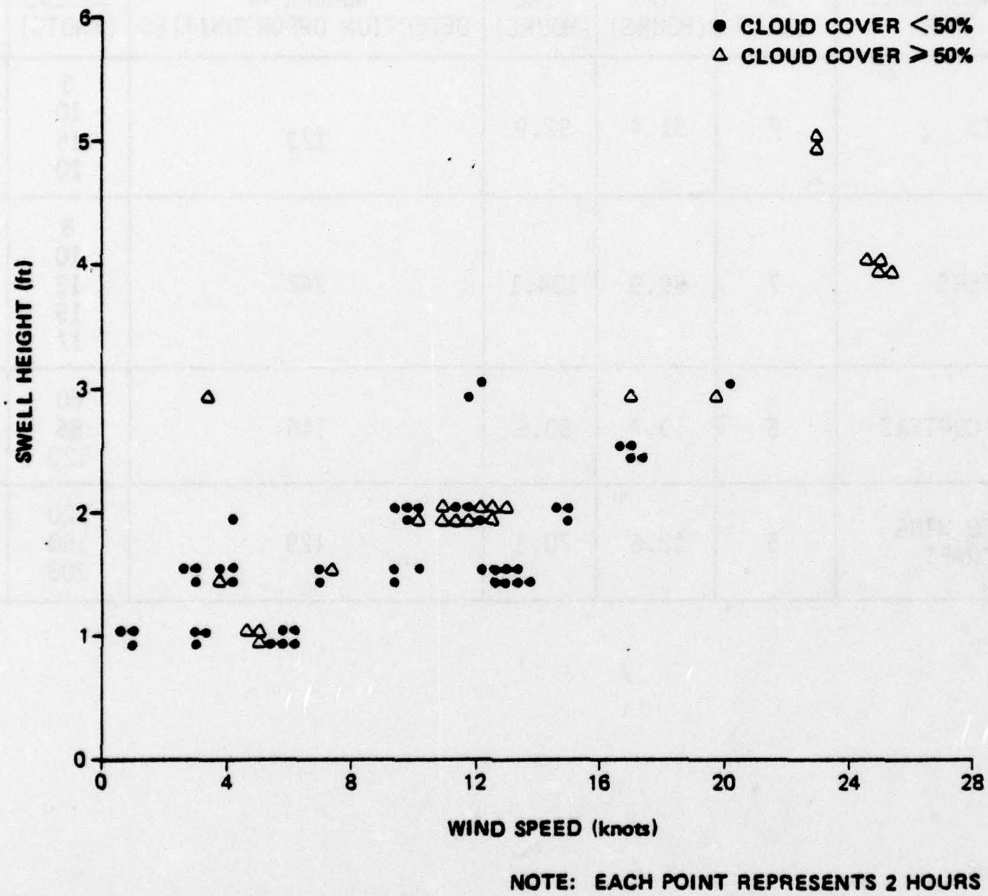


FIGURE 2-4. DISTRIBUTION OF WIND SPEED, SWELL HEIGHT, AND CLOUD COVER

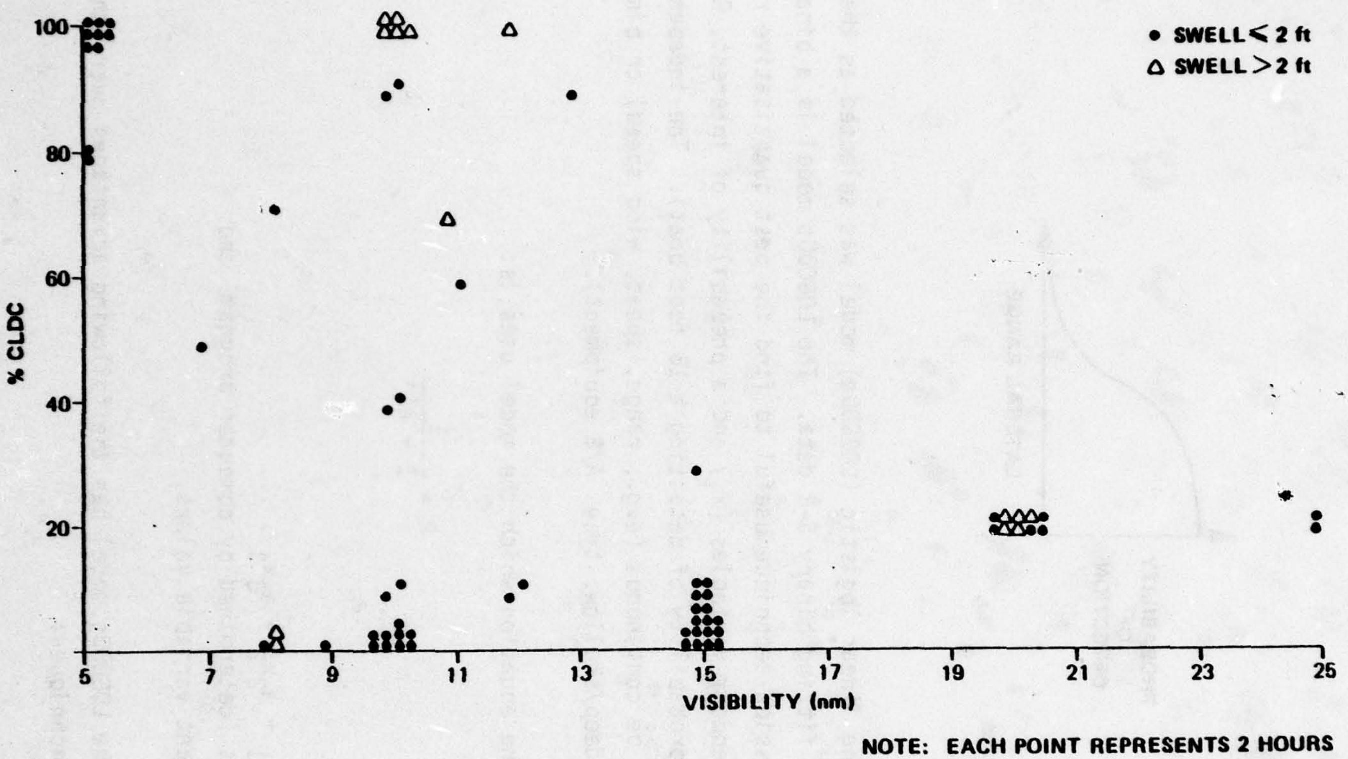
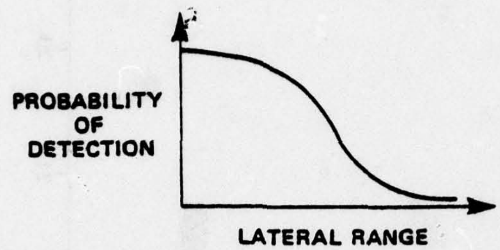


FIGURE 2-5. DISTRIBUTION OF VISIBILITY TO CLOUD COVER



The linear logistic (LOGODDs) model was selected as the best candidate for fitting binary S-R data. The LOGODDs model is a binary, multivariate regression technique useful to find the best quantitative relationship between independent variables (x_i) and a probability of interest, R (in this case the probability of detecting a 16 foot boat). The independent variables (x_i) can be continuous (e.g., range, speed, wind speed) or binary (e.g., day/night, deep/shallow, type A/B equipment).

The equation which the model uses is:

$$R = \frac{1}{1 + e^{-\lambda}}$$

where

$\lambda = a_0 + a_1x_1 + a_2x_2 + a_3x_3 \ldots$
a_i = constants (determined by computer program) and
x_i = independent variable values

The LOGODDs model has the following advantages over other candidate models/techniques:

1. The model implicitly contains the assumption that $0 \leq Pr$ (Success) ≤ 1.0. A linear model does not, unless the assumption is added to the model (and then computation can become exceedingly difficult).

2. The model is analogous to normal-theory linear models. Thus, analysis of variance and regression implications can be drawn from the model.

3. The model can be used to observe the effects of several independent or interactive parameters be they continuous or discrete.

4. A regression technique is better than non-parametric hypothesis testing which does not yield quantitative relationship between the probability in question and values of the independent variables.

The primary disadvantages of the LOGODDs model are:

1. The dependent variable (probability of detection) must be a monotonic function of the independent variables.

2. The computational effort is substantial, requiring use of computer techniques.

The following sections describe raw data development, analysis conducted to ensure that the experiment data met the criteria for application of the LOGODDs model, and evaluations conducted to determine the goodness of fit of the experiment data to the LOGODDs model. Appendix A provides a more detailed description of the LOGODDS model.

2.7.2 Development of Raw Data. Valid sightings of SAR targets were determined by comparison of sighting reports (maintained by observers onboard SRUs) to the reconstruction. Reconstruction provided searcher tracks annotated with time and target positions. For each sighting recorded, the time of the sighting, the estimated range and relative bearing were compared to actual target positions. If a sighting was determined to be a valid detection, the lateral range and values of other explanatory variables were recorded. The maximum lateral range for all detections of a particular searcher on the day in question was determined. The value was multiplied by 1.5, and became the criterion for evaluating detection opportunities.

The value of 1.5 was selected to provide an appropriate mix of misses and detections. Any target whose lateral range was less than or equal to 1.5 times the maximum lateral range of a valid detection that was not recorded as a sighting, was determined to be a "miss". The lateral range and other explanatory variables for misses were recorded in the same manner as for sightings. Thus, a separate raw data file was developed for each search unit on a particular day that included all valid target sightings, and all "misses" that met the criterion above. Raw data is included in Appendix B.

2.7.3 Aggregation of Data. The target detection data described in the previous section was aggregated separately for each SRU on each day. The performance data for all SRUs of a specific type (e.g., cutters) was then examined closely to determine whether it could be aggregated. For example, for each cutter on each day, the mean opportunity range and average probability of detection were plotted. Lateral range curves were also developed using the raw data. This allowed the analyst to determine if, after correcting for different environmental or kinematic conditions, any cutter performed better or worse than other cutters. No significant differences between SRU units of the same type were noted for cutters, SAR boats, helicopters, or fixed wing aircraft.

The aggregated data for each type SRU was then used to develop empirical lateral range curves by binning on lateral range the ratio of detections to opportunities for selected values of other explanatory parameters. Figure 2-6 shows representative plots for cutters of probability of detection versus lateral range for two environmental conditions. Note that the "best fit" curves for both cases demonstrate the classic S-R curve characteristic previously discussed.

A comparison between types of SRUs was made to determine if aggregation of data over different type SRUs appeared feasible or whether the performance of one type SRU was affected differently than the performance of another by the same changes in explanatory variables. This comparison indicated that aggregation of cutter and boat data, and aggregation of helicopter and fixed wing aircraft data was appropriate.

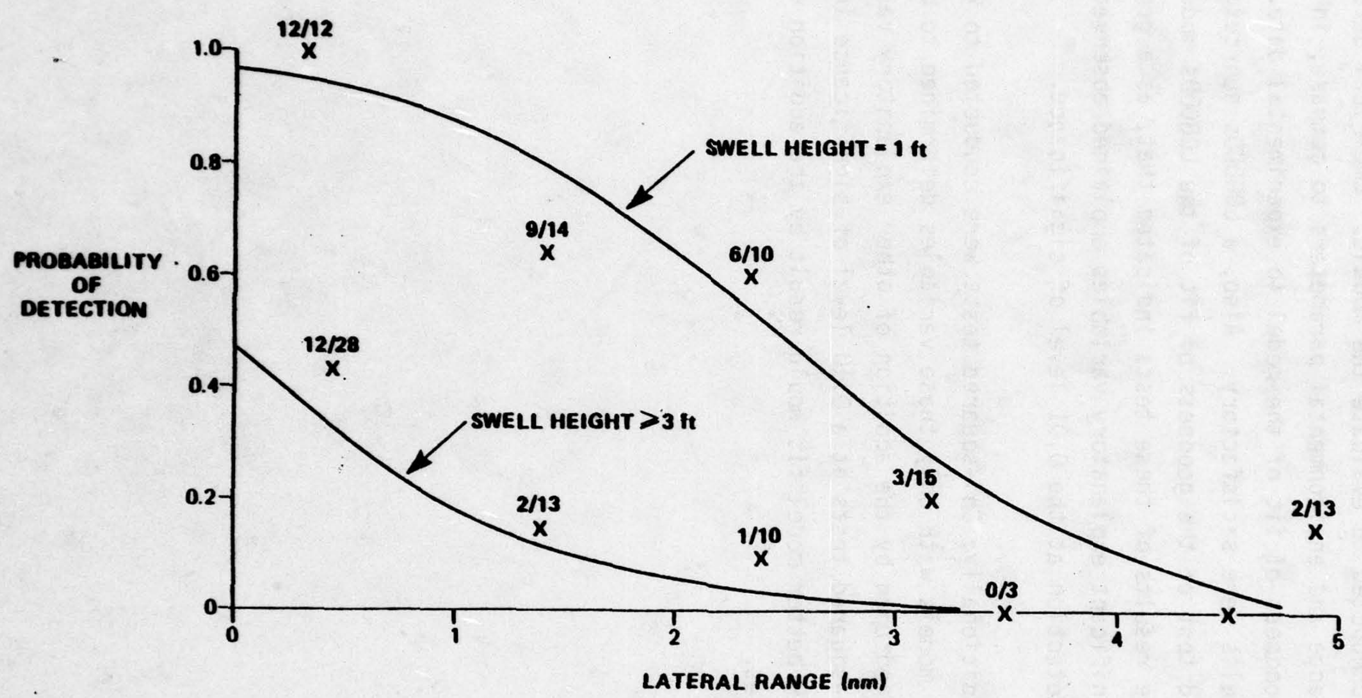


FIGURE 2-6. EMPIRICAL DATA FOR CUTTERS

2.7.4 LOGODDs Model, "Goodness of Fit". Once the computer runs had been conducted to develop the LOGODDs models for each unit type, "goodness of fit" tests were conducted to evaluate the models. Empirical data was binned by lateral range and environmental parameters to compare, in a qualitative sense, the goodness of fit of the model to experimental data. In all cases these results were satisfactory. Also, a LOGODDs subroutine performed a Chi-squared test of the goodness of fit of the LOGODDs models to empirical data. The results of these tests indicated that, as a group, the models with significant explanatory variables explained observed variation in probability of detection at the 0.01 level of significance.

Additionally, Chi-squared tests were conducted to determine whether the LOGODDs models with only those variables determined to be significant could be improved upon by the addition of other explanatory variables. In no cases did Chi-squared tests at a 0.10 level of significance indicate that a significantly better model fit would result by the addition of other explanatory variables.

CHAPTER 3
ANALYSIS RESULTS

3.0 INTRODUCTION

Sections 3.1 and 3.2 of this chapter contain tables of sweep width for surface craft (41/44 foot boats and cutters) and aircraft (fixed-wing aircraft and helicopters). The sensitivity of sweep width to significant environmental and kinematic parameters is discussed for each SRU type. Section 3.3 provides a comparison of search performance for all of the SRU types. Section 3.4 compares sweep width estimates from this experiment with the sweep width tables of the SAR Manual.

3.1 Surface Craft Results

The experiment provided a total of 247 detection opportunities for cutters and 173 detection opportunities for 41/44 foot boats. The variability in probability of detection for the opportunites.was explained at a 0.01 level of significance (a goodness of fit to the model with 99 percent confidence) by a combination of the following explanatory variables:

1. Lateral range
2. Wind speed
3. Swell height
4. Cloud cover
5. Duration of search
6. Search Unit Type

For all environmental conditions, cutter search performance was found to be somewhat better than that of 41/44 foot boats.

3.1.1 41/44 Foot Boat Sweep Widths and Lateral Range Curves. Parameters found to have a significant influence on sweep width for 41/44 foot boats were wind speed, cloud cover, swell height and search duration. Table 3-1 presents estimates of 41/44 foot boat sweep width and 90 percent confidence

bounds for environmental conditions that occurred during this experiment. As shown, sweep width decreases markedly when environmental conditions are significantly degraded.

TABLE 3-1. SWEEP WIDTH VALUES FOR 41/44 FOOT BOATS*

SWEEP WIDTH (nm)**	ENVIRONMENTAL CONDITIONS		
	WIND SPEED (KNOTS)	CLOUD COVER (%)	SWELL HEIGHT (FEET)
4.8 ±.8	1	0	1
3.1 ±.6	10	0	2
2.9 ±.6	12	0	2
2.5 ±.5	12	50	2
2.1 ±.7	12	100	2
1.8 ±.6	15	20	3
1.3 ±.5	15	100	3
0.6 ±.4	20	100	4

*Sweep width values are calculated for a mean search duration of 2 hours.
**Value shown is best estimate of sweep width and 90 percent confidence interval (i.e., 95% confidence that the sweep width is no less than the lower bound).

Figure 3-1 is a graphic display of these results. Extrapolated values are an extension of the model in regions of low cloud cover/high wind speed and high cloud cover/low wind speed. Since there was limited experimental data collected in those regions, it is cautioned against using these extrapolated results. Sensitivity of sweep width to wind speed, swell height, and cloud cover is shown. Note that sweep width is more sensitive to changes in wind speed and swell height than to changes in cloud cover. This is to be expected since the target was a low freeboard, white 16 foot boat. When swell height is about 3 feet or greater, the target may be completely masked when in wave troughs. Further, as wind speed increases, and whitecaps appear, they can easily be mistaken for small white boats, the false contact rate increases and thus the lookout's effective search rate is reduced.

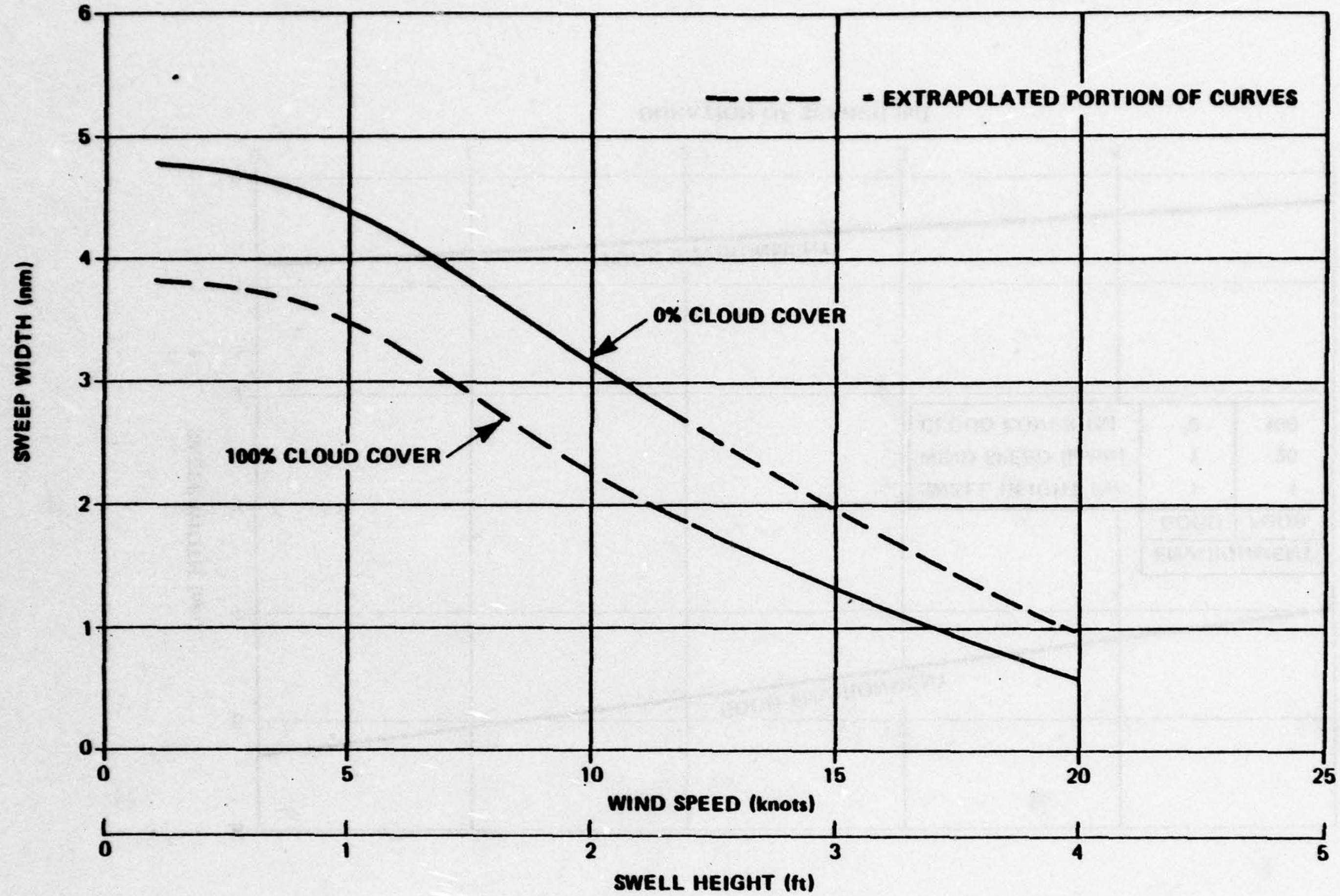


FIGURE 3-1. SWEEP WIDTH AS A FUNCTION OF WIND SPEED/SWELL HEIGHT AND CLOUD COVER

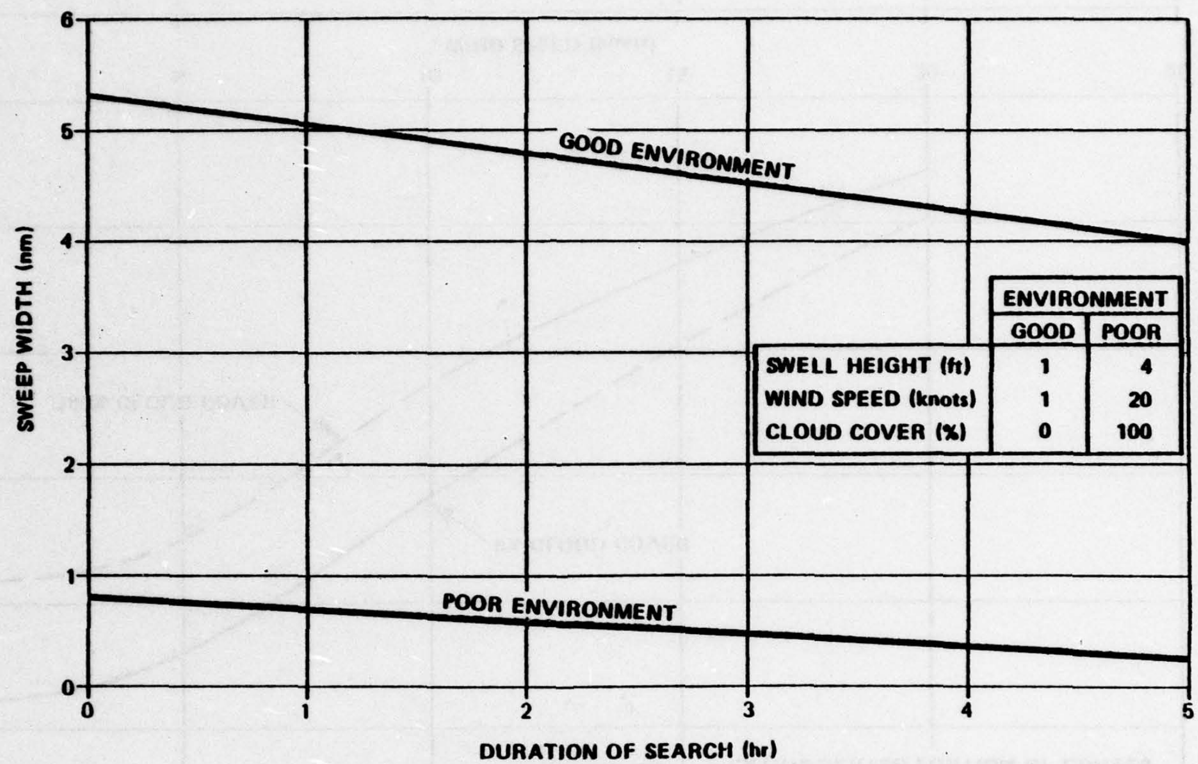


FIGURE 3-2. INFLUENCE OF SEARCH DURATION ON SWEEP WIDTH (41/44 FOOT BOATS)

Figure 3-2 displays sensitivity of sweep width to duration of search under good and poor environmental conditions. Over a span of 4 hours, sweep width decreases 19 percent under good environmental conditions and 43 percent under poor environmental conditions. This difference may be explained by the more severe stress placed upon lookouts under poor environmental conditions, thus reducing search effectiveness at a faster rate.

Figure 3-3 presents lateral range curves for 41/44 foot boats under good and poor conditions. Under good conditions, detection probability is near 100 percent for targets that pass close aboard. Under poor conditions however, detection probability drops to less than 35 percent for these same targets, indicating that whitecaps and target masking in wave troughs remain a problem, even at near zero lateral ranges.

Visibility was greater than or equal to 10 nautical miles during 95 percent of the 41/44 foot boat search time. This is considerably greater than the longest of 41/44 foot boat detection opportunities. Thus it is not surprising that visibility was not identified as a significant variable. However, had a portion of these searches been conducted at visibilities of 5 nautical miles or less, it is postulated that visibility would have been identified as a significant variable.

About half of the 41/44 foot boats searches were conducted at maximum speed (20 knots for 41 foot boats and 10 knots for 44 foot boats) and the remainder at about 10 knots. Searching at maximum speed did not significantly degrade search performance (sweep width). It is postulated that this was the case because, even at maximum speed, lookouts had ample opportunity to conduct a thorough scan of their assigned areas. The incremental increase in probability of detection resulting from additional scans possible at slower speeds was therefore small.

Searches generally commenced in mid-morning and were completed by mid-afternoon. During this time frame, the elevation of the sun varied from about 30 to 50 degrees. Little if any difference in target-to-background contrast or glare is predicted over this range; thus it was

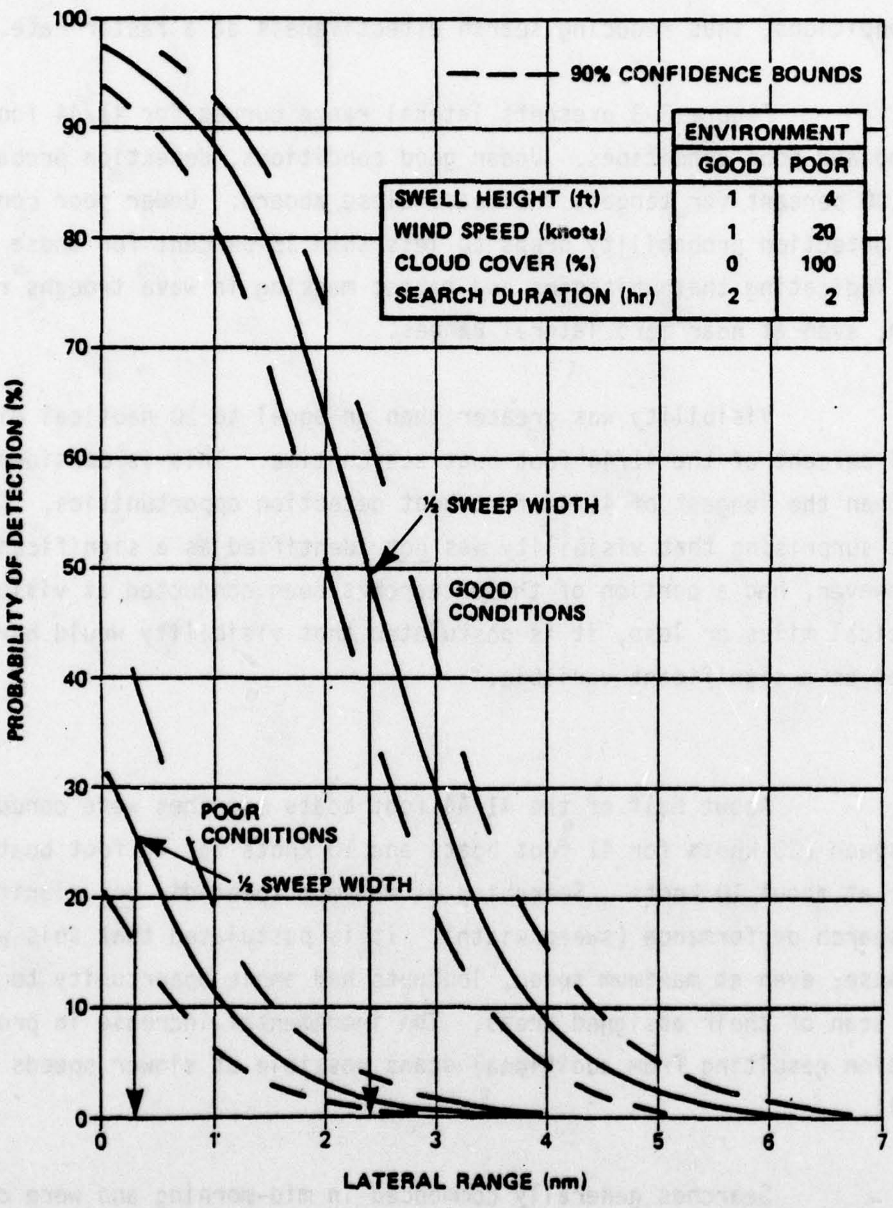


FIGURE 3-3. LATERAL RANGE CURVES (41/44 FOOT BOATS)

not surprising that elevation of the sun was <u>not</u> a significant variable. In order to identify the influence of this variable on probability of detection, it would seem necessary to conduct first/last light searches as well as mid-day searches.

3.1.2 Comparison of 41/44 Foot Boat and Cutter Performance. For all environmental conditions, cutters had larger sweep widths than 41/44 foot boats. This is not surprising because of the physical and operational differences between the units, such as:

1. 82/95 foot cutters are larger, more stable search platforms, providing a higher height of eye, and subject to less disruption by rough weather.

2. Cutters had more lookouts searching at any one time (four versus two for the boats), and additionally, due to their larger crew size, lookouts could be rotated routinely which was not the case for 41/44 foot boats.

3. Because of a more stable platform, cutter lookouts could make better use of visual aids (binoculars).

3.1.3 Cutter Sweep Widths. As was the case for 41/44 foot boats, wind speed, cloud cover, swell height and search duration were the parameters found to have a significant influence on sweep width for cutters. The sensitivity of cutter search performance to changes in these parameters was also found to be the same as 41/44 foot boats (see Section 3.1.1 for further discussion).

Table 3-2 presents estimates of cutter sweep widths and 90 percent confidence bounds for environmental conditions that occurred during this experiment.

TABLE 3-2. SWEEP WIDTH VALUES* FOR 82/95 FOOT CUTTERS

SWEEP WIDTH (nm)**	ENVIRONMENTAL CONDITIONS		
	WIND SPEED (KNOTS)	CLOUD COVER (%)	SWELL HEIGHT (FEET)
5.5 ±.8	1	0	1
3.8 ±.6	10	0	2
3.6 ±.6	12	0	2
3.1 ±.5	12	50	2
2.7 ±.7	12	100	2
2.3 ±.6	15	20	3
1.7 ±.5	15	100	3
0.9 ±.4	20	100	4

*Sweep widths have been calculated holding duration of search constant at its mean value of 2 hours.

**The value shown is the best estimate plus 90 percent confidence bounds (i.e., 95% confidence that the sweep width is no less than the lower bound.)

Figure 3-4 shows the difference in search performance between cutters and 41/44 foot boats for representative environmental conditions. As in Figure 3-1, it is cautioned against using the extrapolated results. Figure 3-5 shows that, under good conditions, the decrease in sweep width, over a 4 hour search, was slightly greater for 41/44 foot boats (19 percent) than for cutters (17 percent). Under poor conditions the sweep width decrease over a 4 hour search is likewise slightly greater for 41/44 foot boats (43 percent) than for cutters (40 percent).

3.2 Aircraft Results

The experiment provided a total of 129 detection opportunities for fixed wing aircraft and 146 detection opportunities for helicopters. The variability in probability of detection for these opportunities was explained at a 0.01 level of significance by a combination of the following explanatory variables:

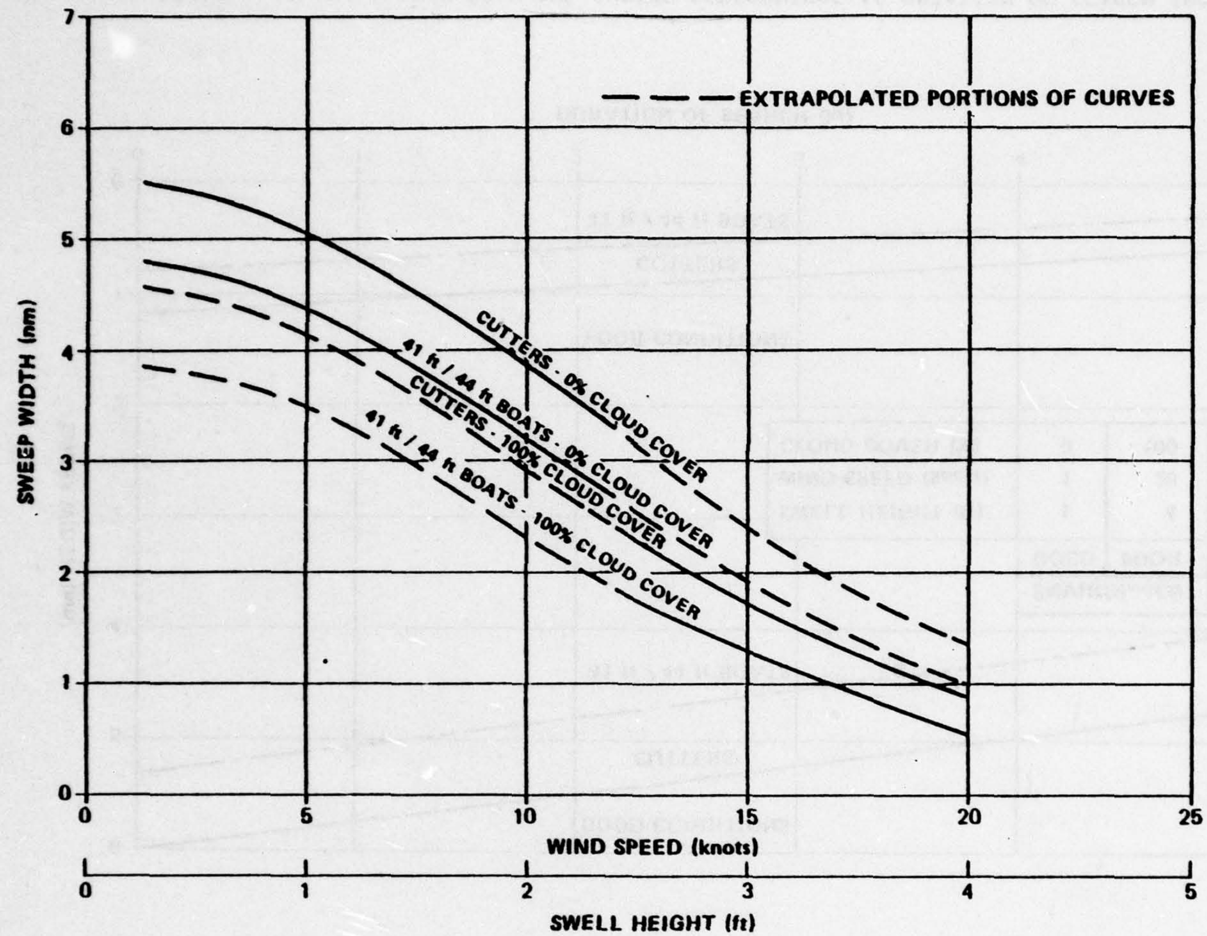


FIGURE 3-4. COMPARISON OF 41/44 FOOT BOATS AND CUTTER SWEEP WIDTHS AS A FUNCTION OF WINDSPEED/SWELL HEIGHT AND CLOUD COVER

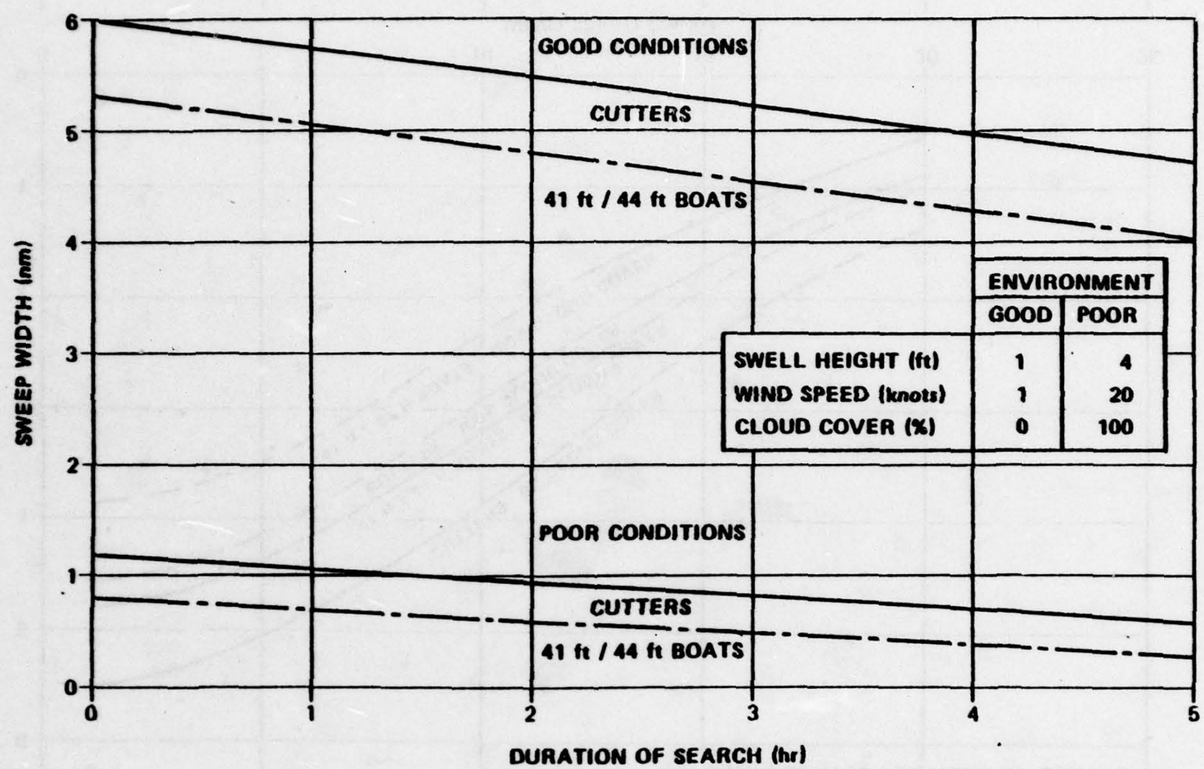


FIGURE 3-5. COMPARISON OF 41/44 FOOT BOAT AND CUTTER PERFORMANCE AS DURATION OF SEARCH INCREASES

1. Lateral range
2. Wind speed
3. Visibility
4. Search Unit type
5. Search speed (fixed wing aircraft only)
6. Search duration (helicopters only).

For the same environmental conditions, helicopter search performance was found to be somewhat better than fixed wing aircraft performance.

3.2.1 Fixed Wing Aircraft Sweep Widths and Lateral Range Curves. Environmental parameters found to have a significant influence on sweep width for fixed wing aircraft were wind speed and visibility. No significant difference in search capability was found between the two different types of fixed wing aircraft (HU-16 and HC-130). Table 3-3 presents estimates of fixed wing aircraft sweep widths and 90 percent confidence bounds for environmental conditions that occurred during this experiment. As was the case for surface craft, as environmental conditions deteriorate, sweep width values decrease.

TABLE 3-3. SWEEP WIDTH VALUES (FIXED WING AIRCRAFT)

SWEEP WIDTH* (nm)	ENVIRONMENTAL CONDITIONS	
	VISIBILITY (nm)	WIND SPEED (KNOTS)
5.9 ±1.1	15	1
4.5 ±.9	15	5
3.8 ±.8	15	7
2.7 ±.7	10	7
2.3 ±.7	8	7
1.9 ±.7	10	10
1.6 ±.6	8	10
1.2 ±.6	8	12

*Value shown is best estimate with 90 percent confidence bounds (i.e., 95% confidence that the sweep width is no less than the lower bound).

The decrease noted in sweep width as wind speed is increased can be explained by the appearance of white caps which look the same as 16 foot white boats. The effect is similar to that experienced by surface craft searchers (see Section 3.1.1). Also, sweep width increased when visibility increased.

Figure 3-6 provides a graphic display of the sensitivity of Table 3-3 sweep widths to changes in wind speed for fixed values of visibility. The two curves for 15 nautical mile and 8 nautical mile visibility are valid (i.e., based on actual data) over the solid portions of the curves and linearly extrapolated over the dashed portions of the curves. The extrapolated portions of the curves are an extension of the model in regions of high wind speed/high visibility and low wind speed/low visibility. Since there was limited experimental data existing in those regions, it is cautioned against using these extrapolated results.

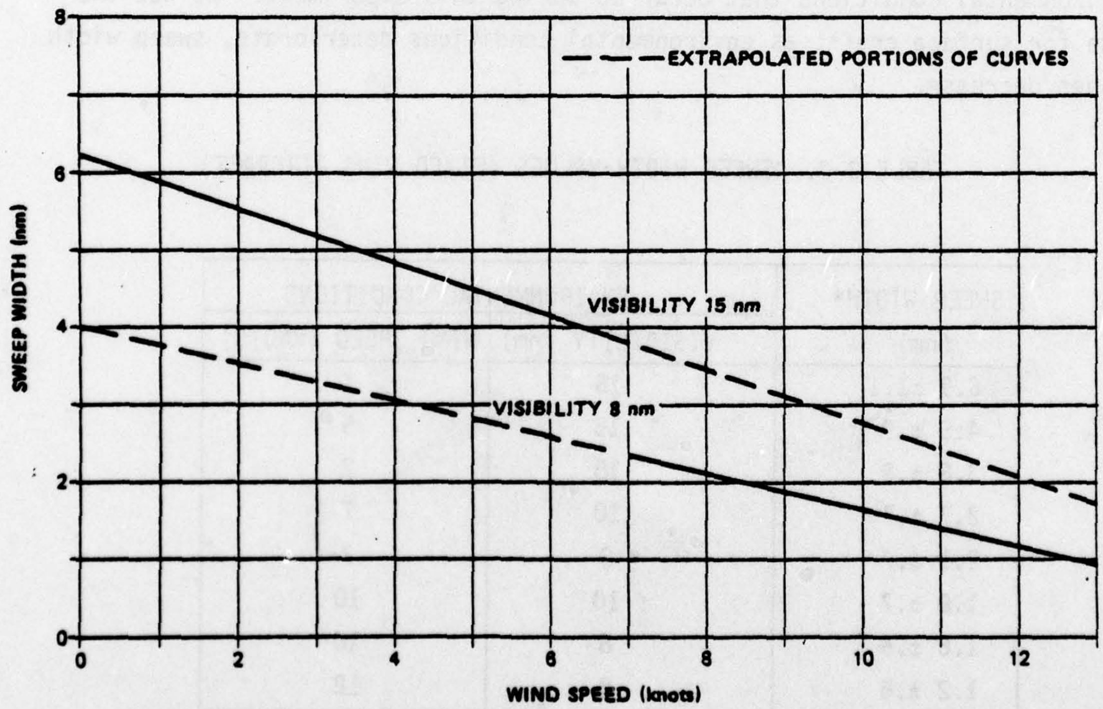


FIGURE 3-6. VARIATION IN SWEEP WIDTH AS A FUNCTION OF WIND SPEED AND VISIBILITY (FIXED WING AIRCRAFT)

Although there was a limited amount of fixed wing aircraft data available (68 observations for HC-130 and 61 observations for HU-16) analysis of this data provided some indications that search speed may also be a significant explanatory parameter for fixed wing aircraft. For example, in Figure 3-7 under good conditions, the sweep width for an HU-16 tended to increase when search speed was decreased from 150 knots to 120 knots and under poor conditions, the sweep width for an HC-130 when speed was decreased from 200 knots to 150 knots. This result seems reasonable since an aircraft lookout at maximum speed may not be capable of making a thorough search of the assigned area in the time available. Thus, as search speed is reduced the effectiveness of the search may increase (i.e., sweep width may increase). Due to the small amount of data available these results should be treated as preliminary, and an effort should be made to gather additional data to confirm the results.

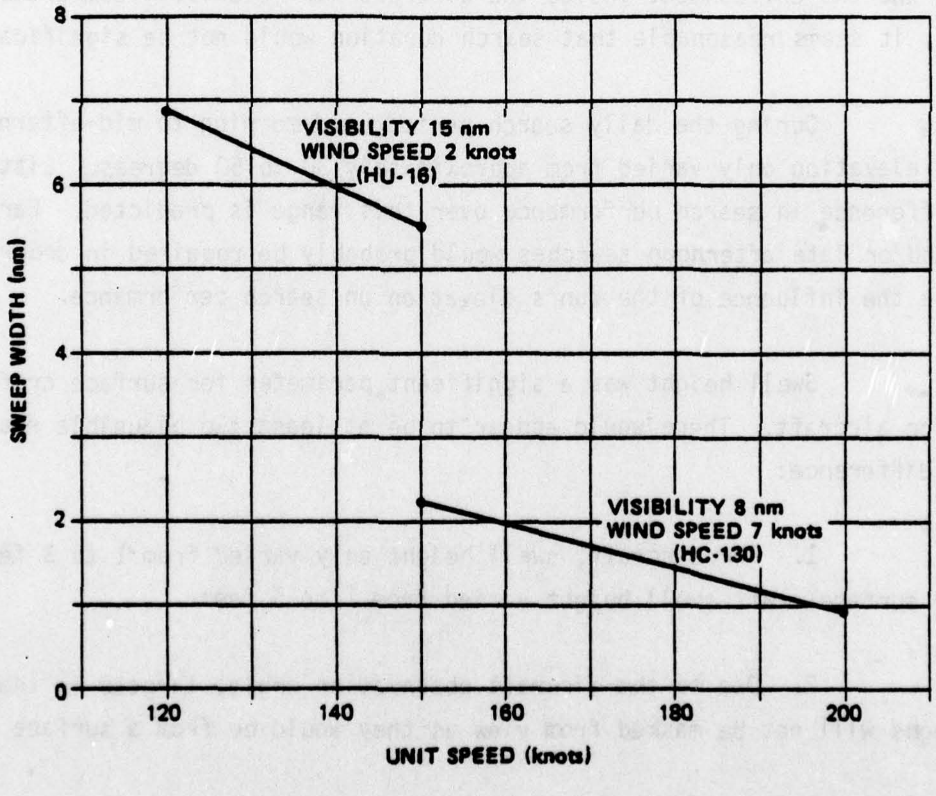


FIGURE 3-7. INFLUENCE OF SEARCH SPEED ON SWEEP WIDTH (FIXED WING AIRCRAFT)

Figure 3-8 displays lateral range curves for fixed wing aircraft under excellent and fair conditions. Of some interest for fair environmental conditions, is the relatively low probability of detection even for targets that pass close aboard. This indicates that perhaps the effect of white caps prevail, even at extremely short lateral ranges.

For the range of environmental conditions experienced during the fixed wing aircraft portion of the experiment, cloud cover, swell height, search duration and elevation of the sun were not found to be significant. The fact that cloud cover was not significant is most likely because there was almost always little or no cloud cover when fixed wing aircraft were searching (i.e., little variability).

Maximum search duration for fixed wing aircraft was about two hours and the environment inside the aircraft was relatively comfortable. Therefore, it seems reasonable that search duration would not be significant.

During the daily search period (mid-morning to mid-afternoon) the sun's elevation only varied from approximately 30 to 50 degrees. Little if any difference in search performance over this range is predicted. Early morning and/or late afternoon searches would probably be required in order to observe the influence of the sun's elevation on search performance.

Swell height was a significant parameter for surface craft but not for aircraft. There would appear to be at least two plausible reasons for this difference:

1. For aircraft, swell height only varied from 1 to 3 feet while for surface craft swell height varied from 1 to 5 feet.

2. Due to the aircraft observation angle, targets in the wave troughs will not be masked from view as they would be from a surface craft.

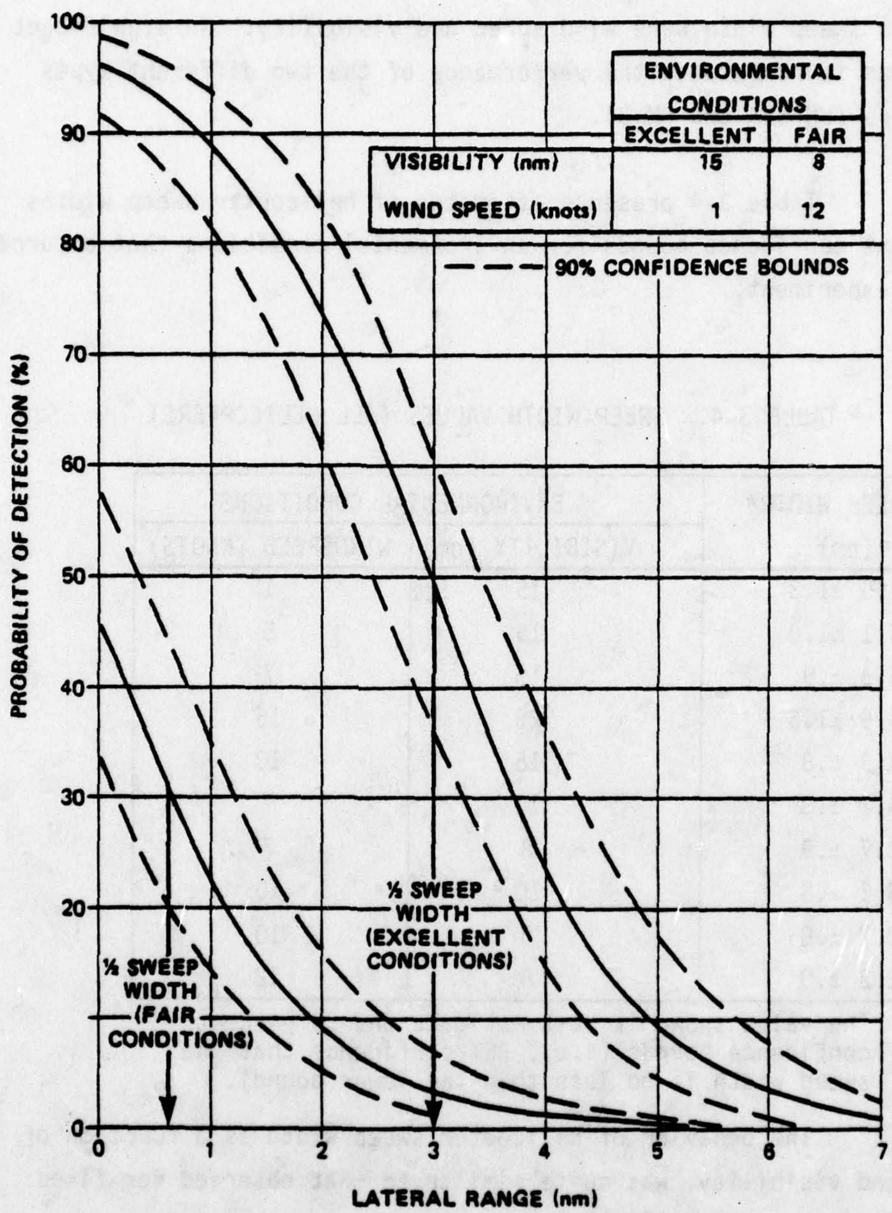


FIGURE 3-8. LATERAL RANGE CURVES FOR FIXED WING AIRCRAFT

3.2.2 Helicopter Sweep Widths. As was the case for fixed wing aircraft, the environmental parameters found to have a significant influence on helicopter sweep width were wind speed and visibility. No significant difference was found between the performance of the two different types of helicopters (HH-52A and HH-3).

Table 3-4 presents estimates of helicopter sweep widths and 90 percent confidence bounds for environmental conditions that occurred during this experiment.

TABLE 3-4. SWEEP WIDTH VALUES (ALL HELICOPTERS)

SWEEP WIDTH* (nm)	ENVIRONMENTAL CONDITIONS	
	VISIBILITY (nm)	WINDSPEED (KNOTS)
7.5 ±1.3	15	1
6.1 ±1.0	15	5
5.3 ±.9	15	7
4.9 ±1.5	25	15
4.3 ±.8	15	10
4.2 ±.8	10	7
3.7 ±.9	8	7
3.2 ±.8	10	10
2.7 ±.8	8	10
2.2 ±.8	8	12

*The value shown is best estimate and 90 percent confidence bounds (i.e., 95% confidence that the sweep width is no less than the lower bound).

The behavior of helicopter sweep width as a function of wind speed and visibility, was quite similar to that observed for fixed wing aircraft (see Section 3.2.1).

Further analysis indicated that search duration was also a significant explanatory parameter for helicopters. For example, Figure 3-9 shows that sweep width decreases from 5.2 to 2.4 nautical miles (54 percent decrease) over a span of 2 hours under conditions of moderate visibility and wind speed. The high noise and vibration helicopter environment is

one possible explanation for the observed decrease in sweep width over a relatively short time.

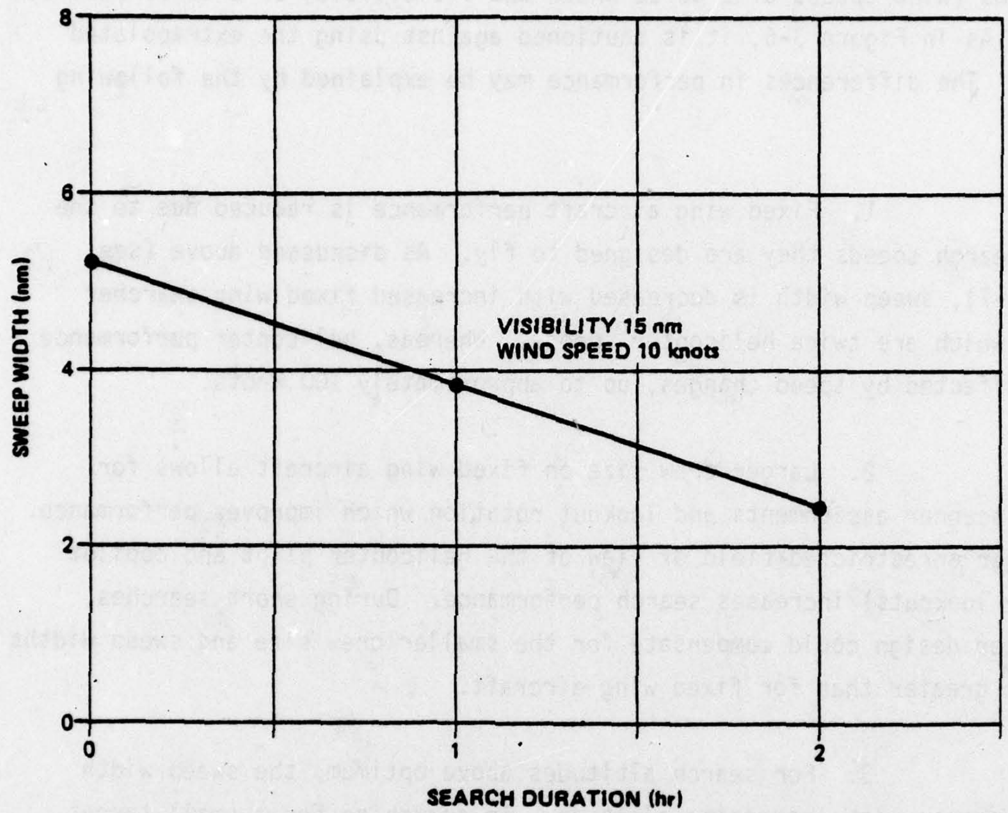


FIGURE 3-9. INFLUENCE OF SEARCH DURATION ON SWEEP WIDTH (HELICOPTER)

As for fixed wing aircraft, cloud cover, swell height, and elevation of the sun were not found to be significant for the range of environmental conditions experienced (see Section 3.2.1 for a discussion of these effects). Maximum helicopter search speed (90 knots) is 75 percent of minimum fixed wing aircraft search speed (120 knots) and only 45 percent of maximum fixed wing aircraft search speed. Thus helicopter lookouts had a greater time to search a particular area. This may explain why search speed was not found to have a significant effect on helicopter search performance.

3.2.3 Comparison of Experiment Results for Helicopter and Fixed Wing Aircraft. As shown in Figure 3-10, during the experiment helicopters consistently outperformed fixed wing aircraft over the range of environmental conditions (wind speeds of 1 to 12 knots and visibilities of 8 to 15 nautical miles). As in Figure 3-6, it is cautioned against using the extrapolated results. The differences in performance may be explained by the following reasons:

1. Fixed wing aircraft performance is reduced due to the higher search speeds they are designed to fly. As discussed above (see Figure 3-7), sweep width is decreased with increased fixed wing searcher speeds, which are twice helicopter speeds. Whereas, helicopter performance is not affected by speed changes, up to approximately 100 knots.

2. Larger crew size on fixed wing aircraft allows for several scanner assignments and lookout rotation which improves performance. The larger unrestricted field of view of the helicopter pilot and copilot (primary lookouts) increases search performance. During short searches, helicopter design could compensate for the smaller crew size and sweep widths would be greater than for fixed wing aircraft.

3. For search altitudes above optimum, the sweep width would decrease with increasing altitude. In searching for a small target (a 16 foot boat), the optimum altitude may be below 1000 feet. Since fixed wing aircraft primarily searched at or above 1000 feet, and helicopters below 1000 feet, fixed wing aircraft performance may have been reduced.

3.3 Comparison of Surface Craft and Aircraft Sweep Widths

Table 3-5 contains sweep width estimates for each search unit type under excellent, good, fair, and poor environmental conditions. Note that under excellent environmental conditions, aircraft had larger sweep widths than surface craft. As environmental conditions deteriorated, however, cutters outperformed all aircraft, and boat sweep widths were approximately the same as those for helicopters, while fixed wing aircraft had the lowest sweep width values. Estimates of sweep width are not provided for aircraft in a poor environment since no aircraft searches were conducted under these conditions.

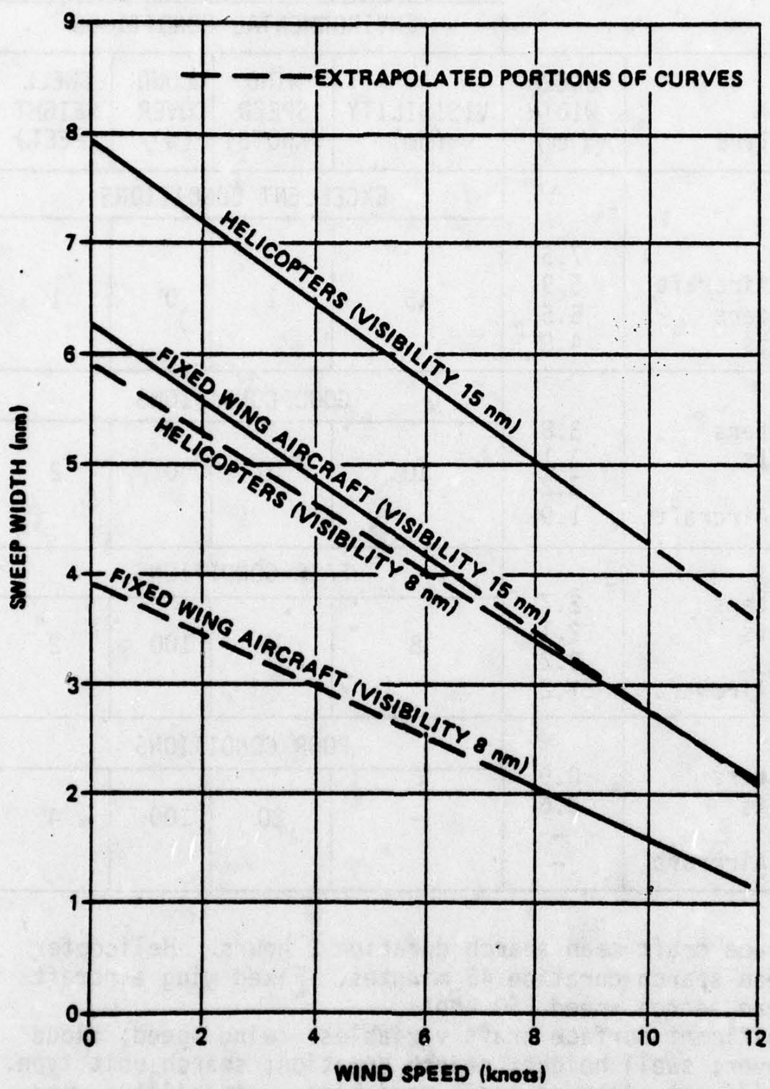


FIGURE 3-10. COMPARISON OF FIXED WING AIRCRAFT AND HELICOPTER SWEEP WIDTHS AS A FUNCTION OF WIND SPEED AND VISIBILITY

TABLE 3-5. COMPARISON OF AIRCRAFT AND SURFACE CRAFT SWEEP WIDTHS

UNIT TYPE	SWEEP WIDTH (nm)	VISIBILITY (nm)	WIND SPEED (KNOTS)	CLOUD COVER (%)	SWELL HEIGHT (FEET)
		ENVIRONMENTAL CONDITIONS			
		EXCELLENT CONDITIONS			
Helicopters	7.5	15	1	0	1
Fixed Wing Aircraft	5.9				
82'/95' Cutters	5.5				
41'/44' Boats	4.8				
		GOOD CONDITIONS			
82'/95' Cutters	3.8	10	10	0	2
41'/44' Boats	3.1				
Helicopters	3.2				
Fixed Wing Aircraft	1.9				
		FAIR CONDITIONS			
82'/95' Cutters	2.7	8	12	100	2
41'/44' Boats	2.1				
Helicopters	2.2				
Fixed Wing Aircraft	1.2				
		POOR CONDITIONS			
82'/95' Cutters	0.9	-	20	100	4
41'/44' Boats	0.6				
Helicopters	-				
Fixed Wing Aircraft	-				

Note: Surface craft mean search duration 2 hours. Helicopter mean search duration 45 minutes. Fixed wing aircraft mean search speed 150 knots.
Significant surface craft variables: wind speed; cloud cover; swell height; search duration; search unit type.
Significant airborne craft variables: visibility; wind speed; search unit type.

3.4 Comparison of Experiment Results with SAR Manual Sweep Width Tables

This section provides a comparison of experiment sweep width estimates for 16 foot boat targets with the guidance currently available for SAR planning (the visual search sweep width tables of the SAR Manual).* The experiment results were compared to the SAR Manuals sweep width tables for two target types:

1. Boats less than 30 feet
2. Life rafts.

3.4.1 Comparison of Surface Craft Results with SAR Manual Sweep Width Tables. Figure 3-11 provides a comparison for experiment environmental conditions of both cutter and SAR boat sweep width estimates with SAR Manual sweep width table values for boats (less than 30 feet) and life rafts. This comparison was made by first selecting environmental conditions from Tables 3-1 and 3-2 that were represented in the sweep width tables, Appendix C. Sweep width values were then plotted against values from the SAR Manual sweep width tables for the same environmental conditions. (A visibility of 15 nautical miles was selected as representative of experiment conditions for surface craft). As figure 3-11 demonstrates, the influence of wind speed from 0 to 10 knots on sweep width was inconsistent with the SAR Manual. The present sweep width tables indicate that sweep width decreases as wind speed decreases from 10 to 0 knots, while the results of this experiment indicated the opposite effect. For low wind speeds, the experiment results for surface craft were nearly the same as the SAR Manual sweep width values for boats less than 30 feet. When wind speed reached 20 knots, experiment results were nearly the same as the SAR Manual sweep width values for life rafts. The implication of these results is, for this experiment, that degradation in environmental conditions had a greater influence on sweep width than predicted by the present model.

*Sweep width tables are included as Appendix C.

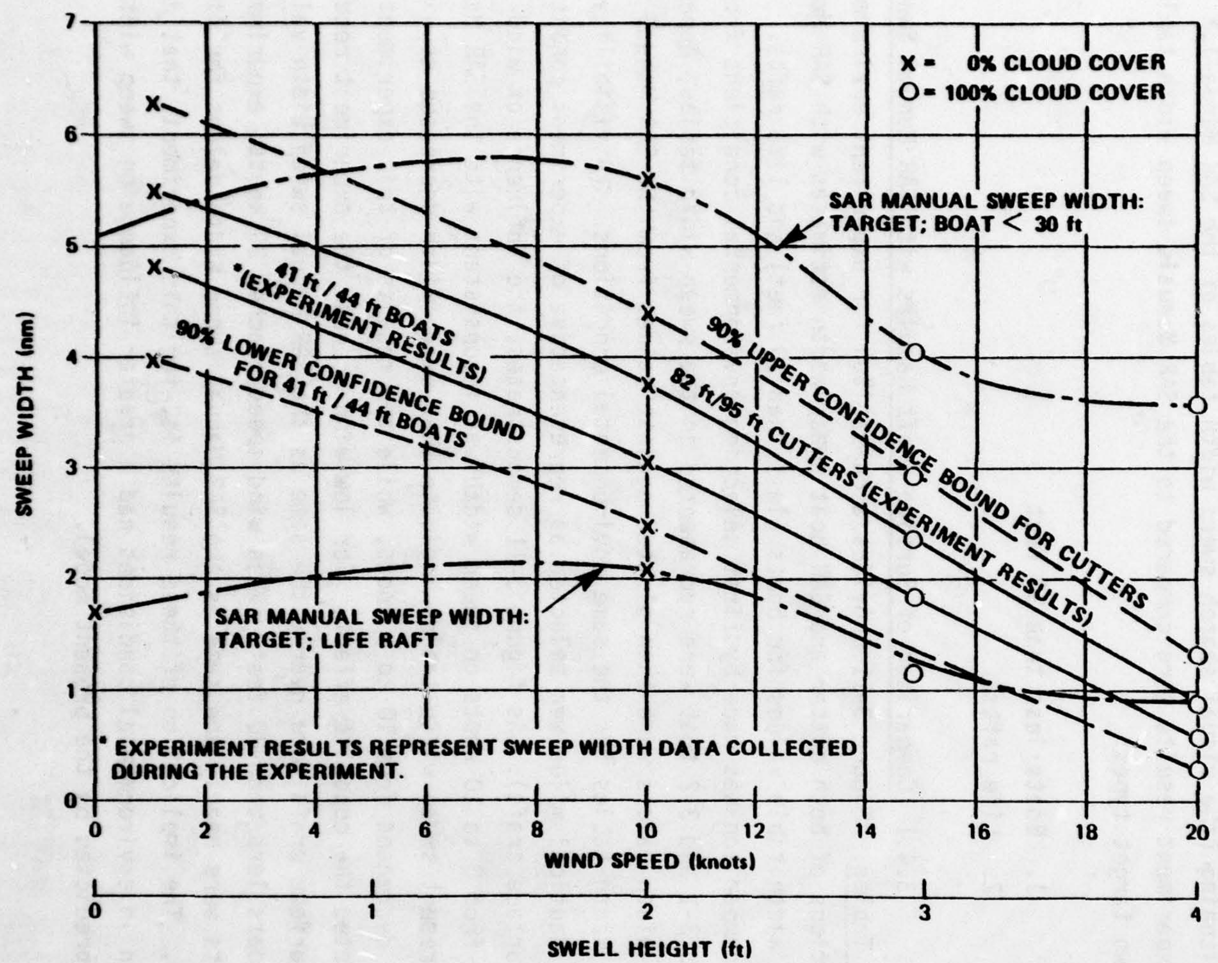


FIGURE 3-11. COMPARISON OF SURFACE CRAFT RESULTS WITH SAR MANUAL SWEEP WIDTH TABLES

3.4.2 <u>Comparison of Aircraft Results with SAR Manual Sweep Width Tables</u>. Figure 3-12 shows a comparison of experiment results for fixed wing aircraft with SAR Manual sweep width table values for boats (less than 30 feet) and life rafts. Note that the experiment results for the range of environmental conditions experienced are nearly the same as the present sweep width predictions for life rafts.

Figure 3-13 shows a comparison of experiment results for helicopters with SAR Manual sweep width table values for life rafts and boats (less than 30 feet). In contrast to fixed wing aircraft results, the helicopter results are more closely approximated by present predictions for boats less than 30 feet. Thus, relative to SAR Manual sweep width tables, helicopters outperformed fixed wing aircraft.

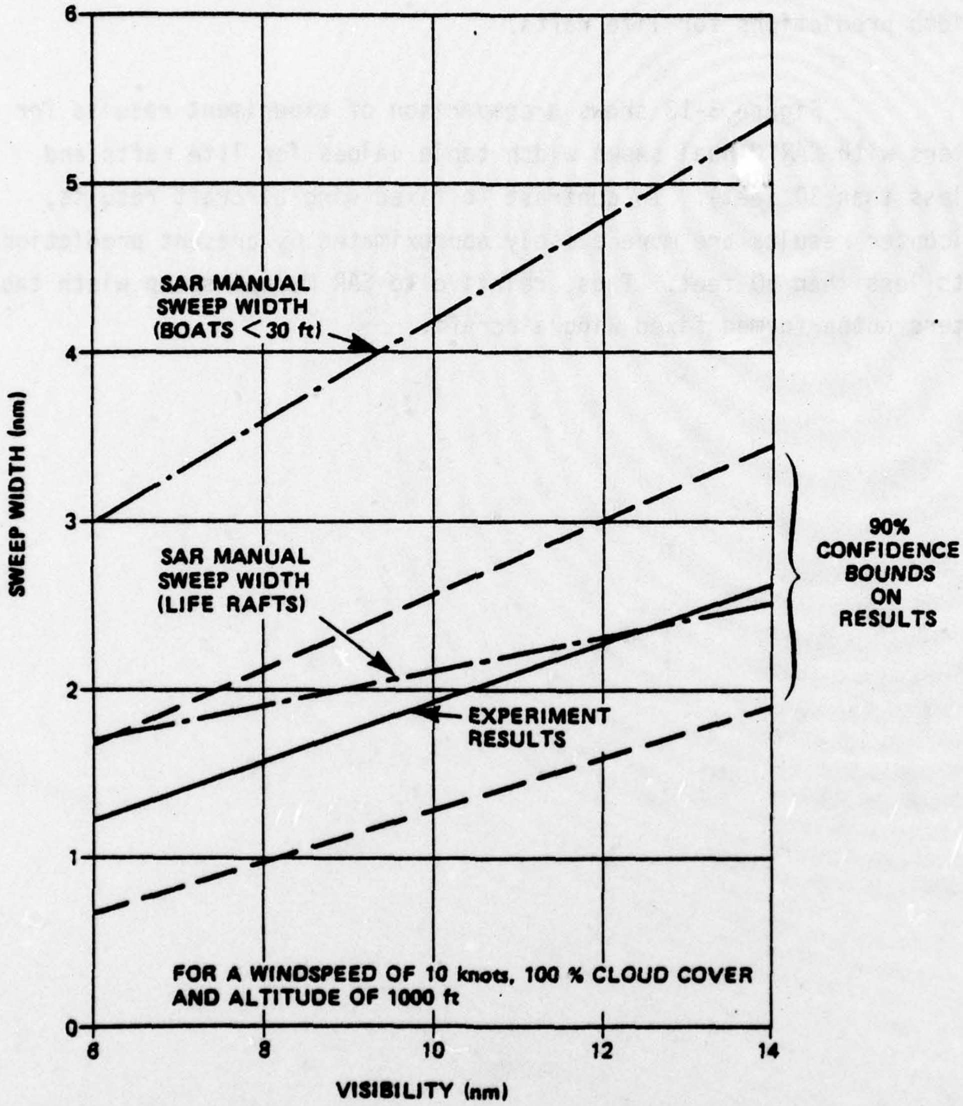


FIGURE 3-12. COMPARISON OF FIXED WING AIRCRAFT RESULTS WITH SAR MANUAL SWEEP WIDTH TABLES

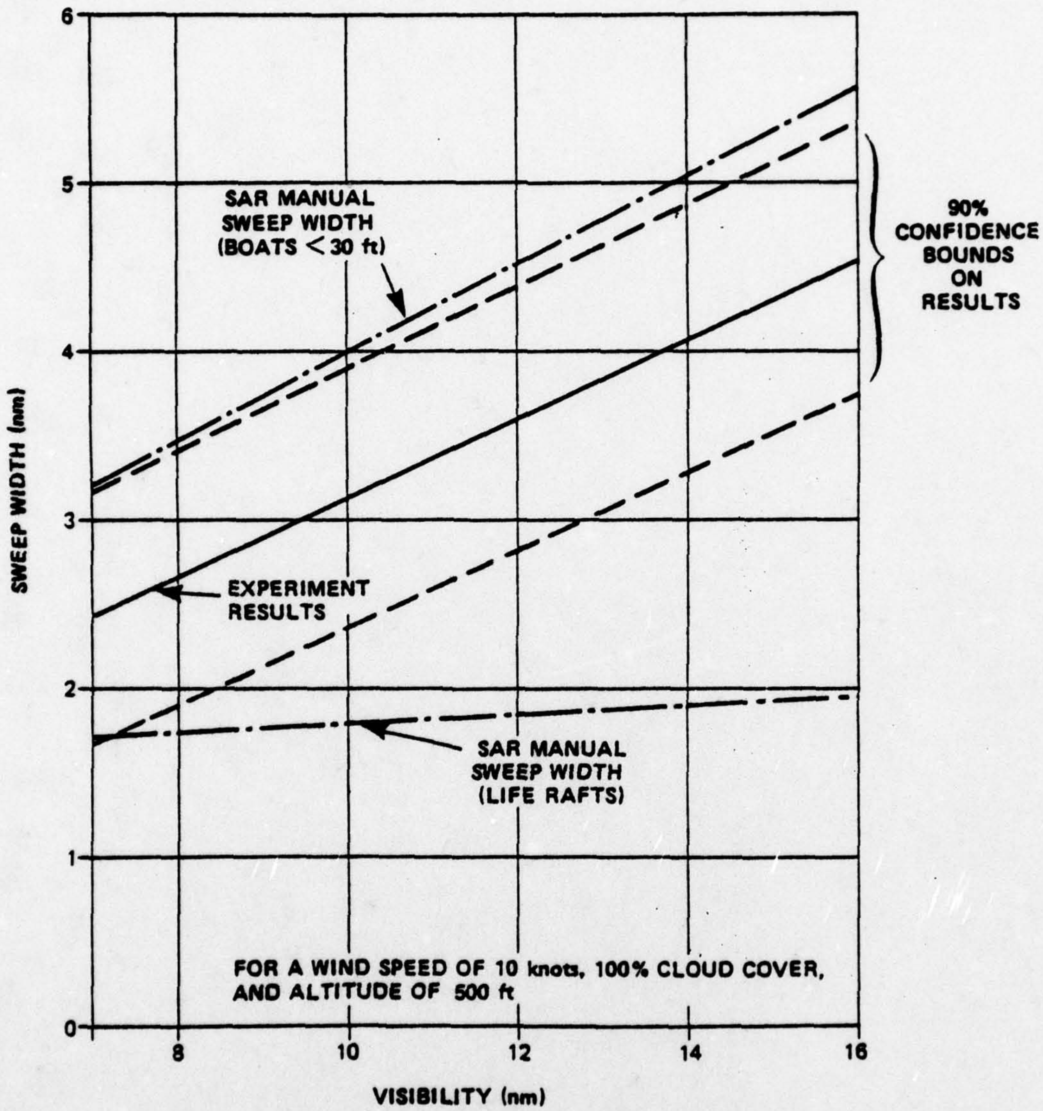


FIGURE 3-13. COMPARISON OF HELICOPTER RESULTS WITH SAR MANUAL SWEEP WIDTH TABLES

CHAPTER 4
CONCLUSIONS AND RECOMMENDATIONS

4.0 CONCLUSIONS

Based upon the results presented in Chapter 3, the following conclusions can be drawn:

1. Since an increase in search speed was not found to degrade search performance, cutters, SAR boats, and helicopters should search for 16 foot boats at the maximum speed that environmental conditions will permit. This will minimize the time required to search a particular area with a given probability of detection. In contrast, for fixed wing aircraft, an increase in search speed was found to reduce sweep width (all other things remain the same). So for fixed wing aircraft, while a higher search speed will reduce the time required to search a given area (for a fixed track spacing), the probability of detection of a 16 foot boat in that area will also be reduced. It is beyond the scope of this report to determine the optimum search speed for fixed wing aircraft but this appears to be a fruitful area for future consideration.

2. Experiment results indicated that surface craft search performance degraded more rapidly as environmental conditions deteriorated than predicted by the SAR Manual (see Figure 3-11). Aircraft did not search under as wide a range of environmental conditions as surface craft. Thus, while a similar conclusion could not be drawn concerning aircraft search performance, there is no assurance that such an effect does not exist. It is postulated that if these targets (16 foot boats) had displayed an inflatable international orange balloon on a 20 foot tether or an international orange smoke signal, search performance would not have shown the dramatic degradation seen as environmental conditions deteriorated. A smaller scale experiment under poor environmental conditions using targets equipped with such safety equipment could quantify the expected improvement in performance.

3. <u>The degradation of surface craft and helicopter performance over the course of a search was significant</u>. For surface craft under marginal conditions (20 knots wind speed and 4 feet swells) after four hours of search, sweep width was reduced by as much as 43 percent (see Figure 3-5). Helicopters exhibited a similar reduction in performance (54 percent) over a two hour search (see Figure 3-9). <u>This</u> dramatic reduction in sweep width as a search progresses, <u>underscores the necessity for understanding the human factors (see section 1.3.2) that contribute to this reduction, so that the effect can, if possible, be reduced</u>.

4. The existing visual search sweep width tables, predict a continual reduction in sweep width as wind speed decreases from 10 to 0 knots. The SAR Manual (USCG, 1973) explains these results by stating that "with small targets on glassy seas. . .difficulty will be experienced in detection due to the reflections of sun, sky, and clouds on the sea surface." The experiment results indicated the opposite influence for all SRU types (i.e., sweep width continually decreased as wind speed increased).

A possible explanation for the difference in results is that for this experiment, even with wind speeds as low as 1 to 2 knots, swell height remained at about 1 foot so that "glassy seas" did not exist during the experiment. It is postulated that, in general, sweep width should decrease as wind speed increases throughout the range of possible wind speeds (0 to 100 knots or more) and that "glassy seas," where cloud and sea reflections would make detection of small target more difficult, are relatively unlikely. For example, the June prototype exercise, where the search target was a simulated person in the water, was conducted on somewhat "glassy seas". Detection performance was excellent, and there was no indication that shadows affected detection performance for this small target. Evidence of the shadow effect described in the SAR manual should be studied in future experiments, so that appropriate instructions can be provided for SRUs searching for small targets at wind speeds from 0 to 10 knots.

5. The type of search unit was found to be a significant parameter in determining sweep width. Cutters performed better than SAR boats and helicopters outperformed fixed wing aircraft. The sweep width tables of the SAR Manual (see Appendix C) give only one sweep width for surface vessel search and a sweep width for each of three different altitudes of aircraft search under any set of environmental conditions. Performance differences among search unit types are indicative of unit characteristics and such distinction should be addressed in the sweep width model.

As discussed earlier, speed and altitude could have been attributed to differences in performance between helicopters and fixed wing aircraft. The SAR Manual predicts an increased sweep width with higher altitude up to 2000 feet. Since it became necessary prior to the experiment to limit each aircraft type to a specific altitude, the effects of altitude on detection are unable to be distinguished in this report and warrant further evaluation.

6. For surface craft, under the most extreme environmental conditions experienced during the experiment (wind speed of approximately 20 knots, 4 to 5 feet swells, and 100 percent cloud cover) the estimated probability of detection for targets that passed close aboard (near zero lateral range) was as low as 32 percent (see Figure 3-3). For the most extreme environmental conditions experienced by aircraft (8 nautical mile meteorological visibility and wind speed of 12 knots) the probability of detection for contacts that passed close aboard was as low as 45 percent (see Figure 3-8).

The relatively low probabilities of detection <u>may not</u> be consistent with the probability of detection versus coverage factor curves of the SAR Manual (Figure 2-3), which is based upon the assumptions that: a) the instantaneous probability of detection is inversely proportional to the cube of the range of the target; b) the searcher precisely navigates the assigned tracks; c) the tracks provide a uniform coverage of the search area. While a comparison of the probability of detection versus lateral

range curves to Figure 2-3 is beyond the scope of this report, this comparison would appear to be warranted to ensure that the probability of detection estimates derived from this figure are accurate over a range of environmental conditions. A related question of the influence of navigational inaccuracies on the probability of detection versus coverage factor curve warrants additional study. For example, a correction factor or separate set of curves for search units with limited navigational capability.

7. While the amount of data collected during this experiment provided a good deal of confidence about the validity of the results, the limited range of environmental conditions experienced, restricts application of these results. In order to allow more general use of results, detection data should be collected for the following additional conditions:

a. Low meteorological visibility (5 nautical miles or less)

b. Wind speed greater than 15 knots and swell height 3 feet or greater (aircraft only)

c. First/last light searches (elevation of sun less than 30 degrees)

d. Overcast days (aircraft only).

4.1 Recommendations for Future Experiment Design

Based upon lessons learned during the conduct of this experiment, and subsequent reconstruction and analysis, the following recommendations are presented for improving the quality and efficiency of similar future experiments.

4.1.1 Reconstruction of Searcher Tracks. The MRS proved to be an accurate and generally reliable means of reconstructing the searcher tracks. For this experiment, the MRS system was not available for fixed

wing aircraft due to difficulties in mounting responders on the aircraft. As a result, reconstruction accuracy suffered and the time necessary to reconstruct fixed wing aircraft tracks was increased. Thus, it is recommended that every effort be made for future experiments to have the MRS available to monitor the tracks of all search units. Additionally, to aid in reconstruction, particularly when the MRS is not available or has malfunctioned, each SRU should maintain a plot for each search. If this track is not normally maintained by the crew then the task should be assigned to an observer (an additional observer may thus be required). This track should be accurately annotated with time, particularly for turn points, navigational fixes, and additionally at 15 minute intervals for surface craft, and 2 minute intervals for aircraft.

Consideration should be given to providing more automation in reconstruction by recording the MRS output on magnetic tape for direct input to a computer. (This would also reduce manpower requirements.) If possible two baselines should be provided for the MRS to (1) ensure that a unique solution for target position can be determined, and (2) improve system reliability.

4.1.2 <u>Pre-Search Briefings</u>. It is highly recommended that, before the commencement of any detection exercise, 15 to 30 minutes be provided for a pre-search briefing of each SRU by the observers. This time should be spent to ensure that the search tracks are properly plotted, that the experiment instructions and objectives previously provided to the SRUs are clearly understood, review communications procedures for target sightings, and ensure that necessary annotation of track charts is understood.

4.1.3 <u>Search Area Considerations</u>. The selected search area should have the minimum amount of boat traffic possible, particularly for aircraft, to prevent a target density that overloads both the searcher and the observers. This objective may be met, to some extent, by conducting the experiments during the "off-season" for pleasure boat traffic,

and by excluding popular fishing spots from the search area.

4.1.4 Data Collection Methods. Based upon reconstructed tracks and sighting reports, the analyst must make a determination as to whether sightings reported were valid detections of actual targets. This determination is sensitive to the reliability and accuracy of the information in the sighting reports.

The range, relative bearing, and time estimates included in the sighting reports should be as accurate as the means onboard the SRU for determining these parameters will allow. If possible, these estimates should be independently checked (or recorded) by another individual. For sightings where the vessel is confirmed to be an actual target, the sighting report should so indicate. For aircraft in particular, consideration should be given to an audio recording of the internal communications system, along with a video recording of the aircraft instruments (altitude, course, speed, and time) as a backup to the sighting reports.

4.1.5 Schedule. If possible, one day during each week of the experiment should be left open to allow time for equipment repairs, communications and scheduling of future resources, preliminary data analysis, and administrative matters. On two of the seventeen days scheduled, the experiment was cancelled because the weather precluded target placement and recovery, and on one other day, because of MRS equipment problems. Additionally, on the 14 days when the experiment was conducted, 8 of the 54 units scheduled were unable to participate due to actual SAR missions, equipment failures, or other commitments. Thus, experience would indicate that about 30 percent more resources or test days than the minimum estimated as necessary to meet the experiment requirements should be scheduled.

4.1.6 Scope of Future Efforts. In order to make comprehensive recommendations on changes to the National Search and Rescue Manual visual sweep width tables, experiments with the following additional types of SAR targets should be conducted:

1. Persons in the water (PIW)
2. Life rafts
3. 30 foot boats
4. 45 foot boats.

The data base developed from this experiment for surface craft 420 observations) was evaluated as adequate (over the range of conditions experienced) for determining significant explanatory variables and estimating the sensitivity of sweep width to changes in these significant variables. However, the data base for aircraft (257 observations) resulted in some experimental limitations. For example, aircraft altitude was, to the extent possible, held constant throughout the experiment. In order to provide a greater opportunity to determine significant environmental parameters, and to better quantify their influence on sweep width, aircraft data base should be increased (a specific recommendation follows).

Additionally, it is recommended that an attempt be made to conduct future experiments over as wide a range of environmental conditions as is operationally feasible. This might mean, for example, that experiments be scheduled at those times of year when environmental conditions are most variable. Also, additional days beyond the necessary minimum expected, might be scheduled so that experiment planners could choose days to conduct the experiment when the desired environmental conditions were expected, and cancel the experiment on other days.

Note that there is an implicit tradeoff involved in increasing the range of environmental conditions. For a given data base size, by increasing the range of environmental conditions, the model developed will have applicability over a broader range of conditions, but the "goodness of fit" of the model at any particular point may be reduced. With the model used to evaluate the exercise data (LOGODDS) the goodness of fit should not suffer substantially with an increase in the range of the data as long as the relationship between the explanatory variables and sweep width remains a monotonic function of the large

range of conditions. Therefore, it would be appropriate to establish as goals for each target type in future experiments, the following:

1. A data base of 450 observations each for surface craft and aircraft. (These observations should be as evenly divided as possible between unit type (i.e., helicopters and fixed wing aircraft).)

2. As great a range and mix of environmental conditions as is feasible (i.e., low visibility with high and low wind speeds, etc.).

Based upon these criterion, and assumptions of (1) four experiment days per week, (2) 20 observations per unit per day, (3) four units per day, and (4) a 30 percent cancellation rate, four additional experiments each of about one month in duration would be necessary to evaluate the four additional SAR targets desired. In addition, the duration of each of these experiments should be increased by about one week to evaluate effects such as:

1. Target/background contrast
2. Longer duration searches
3. Dawn/dusk searches.

CHAPTER 5

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APPENDIX A
LINEAR LOGISTIC MODEL

A.0 INTRODUCTION

This appendix provides a description of the linear logistic (LOGODDS) model (Section A.1), a discussion of the general application of the model to empirical data (Section A.2), and an example LOGODDs computer run (Section A.3). An excellent description of the model characteristics and statistical theory applicable when analyzing "yes-no" data is contained in Analysis of Binary Data by D. R. Cox (Chapman and Hall, London 1977). See especially the introductory material (Chapters 1, 2, 3) and the discussion of more complex problems (Chapter 6).

A.1 Model Overview

The LOGODDs model is a binary, multivariate regression technique to find the best quantitative relationship between independent variables (x_i) and a probability of interest, R. For example, R could be a system reliability or an exercise conditional probability. The independent variables (x_i) can be continuous (e.g., range, speed, water depth) or binary (e.g., day/night, deep/shallow, type A/B equipment.*

The equation which the model uses is:

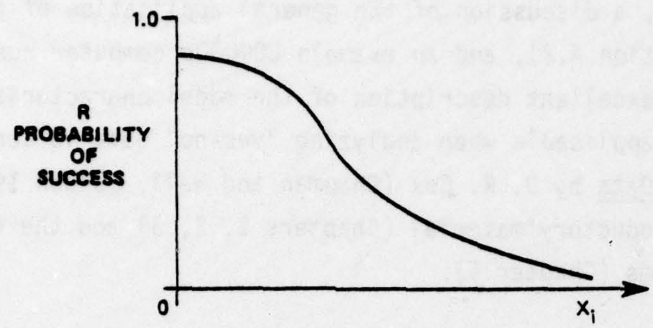
$$R = \frac{1}{1 + e^{-\lambda}}$$

where λ is a function of the independent variables. If λ is a linear function of the independent variables, the basic LOGODDs model can be used. The basic model uses the following expression for λ.

$\lambda = a_0 + a_1x_1 + a_2x_2 + a_3x_3 \ldots$
a_i = constants (determined by computer program) and
x_i = independent variable values

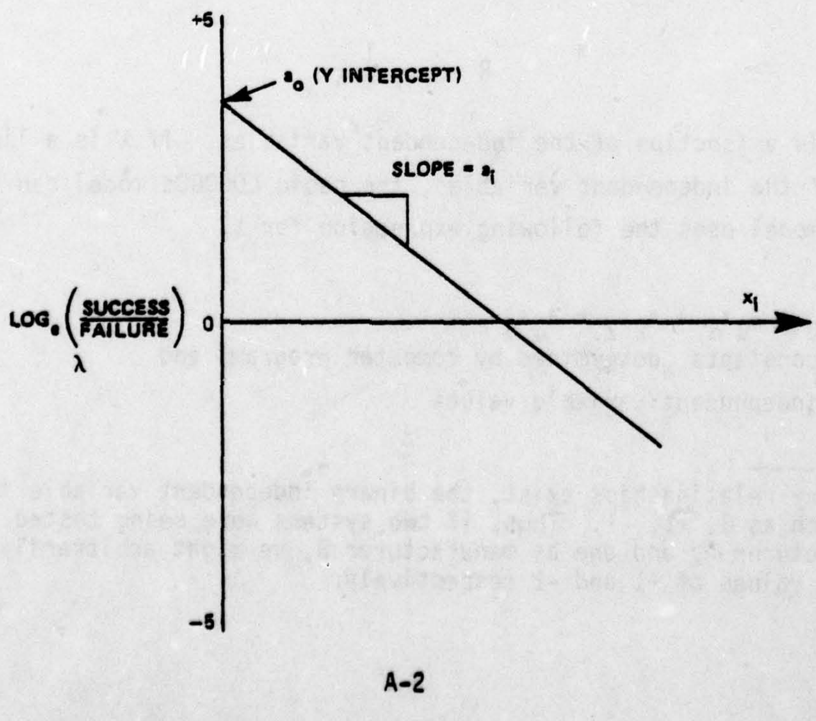
*When binary relationships exist, the binary independent variable is assigned values such as 0, +1, -1. Thus, if two systems were being tested, one made by manufacturer A, and one by manufacturer B, we might arbitrarily assign parameter values of +1 and -1 respectively.

In the basic model, the relationship between R and x_i takes the form shown below when x_i is a continuous variable:



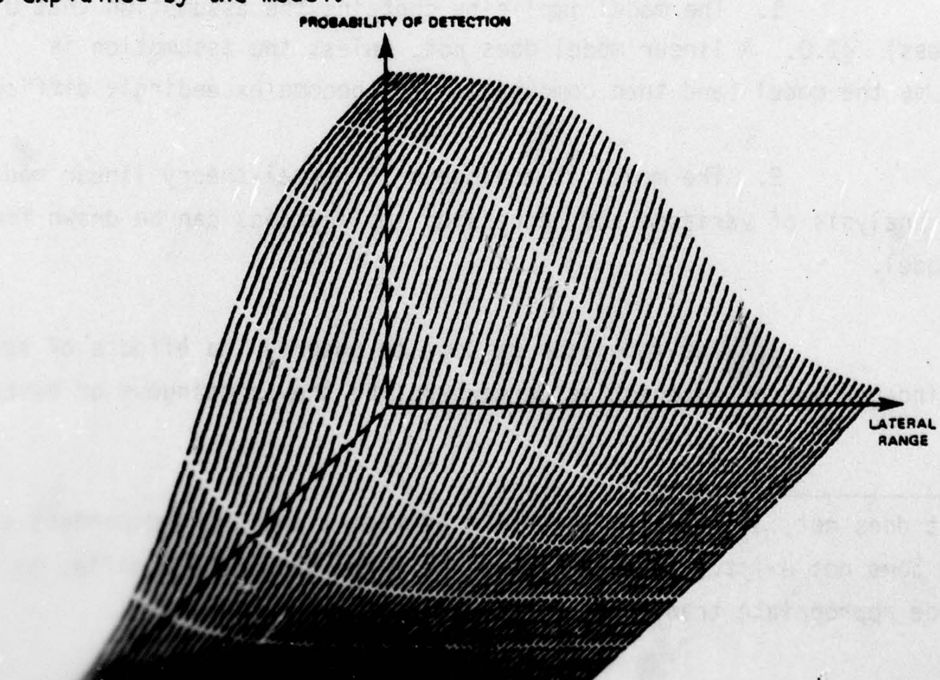
Note that the model restricts the dependent variable, R, to values between 0 and 1. Note also the relationship between R and x_i; a stimulus response curve (S curve) is implied. This type of relationship is often encountered in experimental work.

An equivalent way to view the modeled relationships is shown below. If we plot λ (the log of the ratio of successes to failures) as the dependent variable, it is assumed to be linearily related to the independent variable(s).



Using the computer, it is possible to determine the value of the constants (a_0, a_1, a_2. . .), determine confidence levels on their values, and determine the significance level of the model fit (how much of the observed variability in the independent variable is explained by the dependent variables). By using a step-wise regression technique, non-significant variables (those which cannot be shown to influence the probability R) can be discarded and a best fit can be calculated using only those variables which are found to be significant.

This technique is equivalent to finding the hyperplane which best fits empirical data. For example, suppose the surface shown below best describes the empirical relationship between probability of detection R and two independent variables X_1 and X_2 (e.g., X_1 = lateral range; X_2 = swell height). (Note that the surface would be a flat plane if the log of the odds ratio $\frac{\text{detection}}{\text{misses}}$ were plotted instead of probability of detection.) The computer finds this relationship and ensures that the plane is not parallel to one of the axis. (If parallel, one of the independent parameters has no influence on the probability.) It also tells the user how much of the variability of the data is explained by the model.



Once a good fit has been found, the model can be used to predict the probability value R for different scenarios. Thus, the model is very useful for making comparisons of platform or system performance especially when it is desirable to fix the values of independent variables.

While the logistic model and its associated computer routine is extremely powerful, a note of caution is due. Any model of this sort should not be accepted unconditionally to explain relationships between a probability and explanatory variables of interest; rather, the model should be thought of as a provisional working model to be carefully studied and proven to be most appropriate. In this regard, the raw data should be plotted before the model is applied to ensure that a stimulus response curve exists.* And, once the model is run, goodness of fit criteria should be applied. (The computer routine outputs assist in this area; however, analysis of residuals and other statistical tests are usually warranted). The advantages and disadvantages of the model are listed below.

A.1.1 Model Advantages.

1. The model implicity contains the assumption that $0 \leq$ Pr (Success) ≤ 1.0. A linear model does not, unless the assumption is added to the model (and then computation can become exceedingly difficult).

2. The model is analogous to normal-theory linear models. Thus, analysis of variance and regression implications can be drawn from the model.

3. The model can be used to observe the effects of several independent or interactive parameters, be they continuous or discrete.

*If it does not, a linear relationship between λ and the independent variables does not exist. In such cases, the model should be modified to include appropriate transforms of the independent variables.

4. A regression technique is better than non-parametric hypothesis testing which does not yield an indication of the dependence of the probability in question on the values of the independent variables.

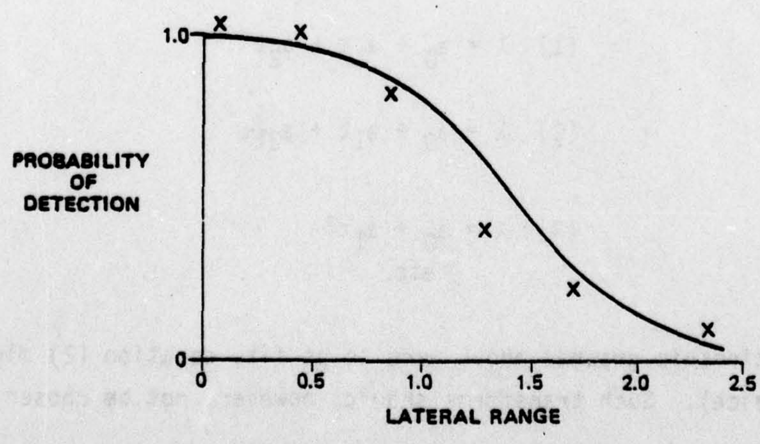
A.1.2 Model Disadvantages.

1. If Pr (Success) is very close to zero or one, the model does not approach its limit as properly as a normal model (but is better than an angular or linear model).

2. The computational effort is substantial requiring use of computer techniques.

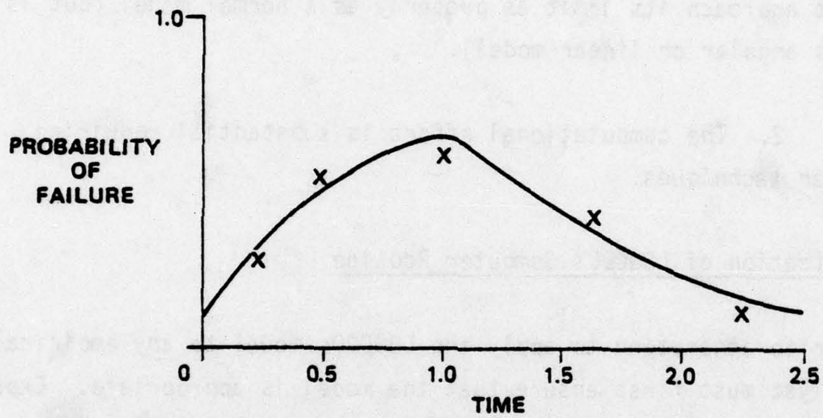
A.2 Application of LOGODDs Computer Routine

Prior to attempting to apply the LOGODDs model to any empirical data, the analyst must first ensure that the model is appropriate. Experience has shown that the best method to make this determination is by plotting the data. Shown below is a graphic example of empirical data for probability of detection versus lateral range, and a fitted curve drawn through the data points.



Data that behaves in this manner is generally appropriate for application of the model.

On the other hand, empirical data of the type shown below would not be appropriate for the LOGODDs model because the dependent variable (probability of failure) cannot be described by a monotonic function of the explanatory variable (time interval from startup).



In such cases, consideration should be given to transforming the explanatory variable or adding another variable which is a higher power of the same explanatory variable. Thus, one might consider model fits such as

$$(1)\quad \lambda = a_0 + a_1 t + a_2 t^2$$

$$(2)\quad \lambda = a_0 + a_1 t + a_2 \frac{1}{t^2}$$

$$(3)\quad \lambda = a_0 + a_1 t^3$$

etc.

(If the relationship graphed above were to be fit, equation (2) might be a good choice). Such transforms should, however, not be chosen on

purely mathematical grounds; a physical reason for such transforms should be evident. Section 2.7 of Cox should be referred to for more details.

Once the analyst has determined that the LOGODDs models can be applied to fit the data, and the data has been properly aggregated (i.e., all aggregated data apparently comes from the same population) the next step is the identification of a good first approximation from which the computer program can start an iterative solution that maximizes the log likelihood function.

In some cases an initial estimate of the coefficients of the explanatory variables can be obtained graphically or by least squares starting with empirical logistic transforms. These methods generally are more applicable when the number of explanatory variables is small. For a larger number of explanatory variables (up to eight variables can presently be accommodated) sorting the data in bins has been most successful. By sorting the data in n + 1 bins, where n is the number of explanatory variables, and calculating the mean values of the dependent variable (reliability) and all explanatory variables for each bin of data, n + 1 independent equations can be developed. These n + 1 equations are input to the LOGODDs computer routine, and a subroutine using matrix algebra solves the equations simultaneously to determine the initial estimates of the explanatory variable coefficients.

Once the initial estimates of the explanatory variable coefficients have been determined, the raw data has been entered, and the desired confidence bounds on the solution have been selected, the LOGODDs computer routine determines a best fit to the raw data through the method of maximum likelihood. The Newton-Raphson iterative solution of the maximum likelihood equations is used. This method is described in section 6.4 of Cox.

A.3 Example LOGODDs Run

This section describes an example of a LOGODDs run. For this run, the dependent variable (R) was the probability that an aircraft would detect a white, 16 foot boat.

$$R = \frac{1}{1 + e^{-\lambda}} = \frac{e^x}{1 + e^x} \quad \text{where } \lambda = x.$$

The explanatory variables were:

1. Lateral range (LATR)
2. Duration of search (FATG)
3. Meteorological visibility (VIS)
4. Wind speed (WDSP)
5. Cloud cover (CLDC)
6. Swell height (SWLL)
7. Search speed (SPED)
8. Unit type (UNIT); HU-16 (1.00) or HC-130 (-1.00)

Figure A-1 shows the initial estimates of the coefficients (D represents 10 to the designated power) for each of the variables above. In this case, these estimates were derived from a LOGODDs run for a similar data set (helicopter searches under the same environmental conditions). However, had these estimates been unavailable, the binning method (described in Section A.2 of this appendix) could also have been used to arrive at these estimates.

Table A-1 shows the unsorted input data for this run. Note that the mean values of each variable are calculated by the model. These can be useful in selecting combinations of variables for LOGODDs plots described later.

Table A-2 provides the initial LOGODDs model solution with all eight explanatory variables. The upper and lower confidence bounds for each coefficient at the selected confidence limits (in this case, 90 percent) are also provided. Any coefficient whose confidence bound contains zero is not a significant variable. Also included with the solution is the associated variance-covariance matrix. On the diagonal from the upper left corner to the lower right corner are the variances associated with the coefficients on the same line. The "-2 Ln likelihood" value is the sum of the squares of the residuals. It is useful for comparing the goodness of fit of different models of the same data base by the use of a Chi-squared test.

After developing the initial model fit to the data base, the LOGODDs routine eliminates the explanatory variable with the largest confidence bound that includes zero (in this case the variable CLDC) and develops another model fit without this variable. Table A-3 shows this model fit. The LOGODDs routine will continue to eliminate explanatory variables, one at a time, until only significant explanatory variables remain. Tables A-4 through A-6 show these LOGODDs models. The significant explanatory variables are lateral range (LATR), visibility (VIS), wind speed (WDSP), and search speed (SPED). In order to determine whether the model with all eight explanatory variables provides a significantly better fit than the simplest model (with only four explanatory variables), a Chi-squared test was conducted comparing the difference between the "-2 Ln likelihood" values for the two models (88.9 - 83.8 = 5.1) for four degrees of freedom (8 variables - 4 variables implies four degrees of freedom lost in going to the four variable model). For a 0.10 level of significance or less, the hypothesis that the four variable model provides the same goodness of fit as the eight variable model cannot be rejected.

Table A-7 shows a LOGODDs model fit for each observation (combinations of significant explanatory variables), plus the upper and lower confidence bounds. The data has been sorted by LATR. The LOGODDs routine allows either a sort on any explanatory variable, or an unsorted output.

Table A-8 shows three "LOGODDs Plots" calculated for lateral ranges from zero to seven nautical miles (at .25 nm intervals) and different combinations of environmental conditions (VIS, WDSP, and SPED). The fitted probability and confidence bounds are shown for each point. Also, the area under the curve is determined, which, in these cases (for a plot with varying lateral range) is one-half the sweep width. The confidence bounds on one-half sweep width are also determined.

Additional information on the LOGODDs routine can be obtained from the program listing or from Cox.

ANALYSIS & TECHNOLOGY, INC.
REGRESSION ANALYSIS USING THE LINEAR LOGISTIC MODEL MOD6

$$R = \frac{E^X}{1+E^X}$$

WHERE $X = A_0 + A_1 Y_1 + A_2 Y_2 + \ldots + A_K Y_K$

AND 0 .LT. R .LT. 1

A_I'S = PARAMETERS OF R - Y_I'S = EXPLANATORY VARIABLES OF R

INPUT VECTOR OF INITIAL ARGUMENTS

A(0) =	-0.10000D 1	
A(1) =	-0.14000D 1	LATR
A(2) =	0.00000D 0	FATO
A(3) =	0.30000D 0	VIS
A(4) =	-0.50000D -1	WDSP
A(5) =	0.00000D 0	CLDC
A(6) =	-0.10000D 0	SWLL
A(7) =	0.00000D 0	SPED
A(8) =	0.00000D 0	UNIT

FIGURE A-1. INITIAL ESTIMATES OF COEFFICIENTS

TABLE A-1. UNSORTED INPUT DATA

OBSVN	SUCCESS(1) FAILURE(0)	LATR	EXPLANATORY VARIABLES FATO	VIS	WDSP	CLDC	SWLL	SPED	UNIT
1	1.0	0.100	0.210	15.0	5.00	0.000	1.50	150.	1.00
1	0.0	3.50	0.170	15.0	5.00	0.000	1.50	150.	1.00
1	0.0	2.75	0.270	15.0	5.00	0.000	1.50	150.	1.00
1	1.0	0.550	0.320	15.0	5.00	0.000	1.50	150.	1.00
1	0.0	3.40	0.400	15.0	5.00	0.000	1.50	150.	1.00
1	1.0	1.58	0.220	10.0	7.00	0.000	1.00	120.	1.00
1	1.0	1.45	0.080	10.0	7.00	0.000	1.00	120.	1.00
1	1.0	0.600	0.130	10.0	7.00	0.000	1.00	120.	1.00
1	0.0	3.20	0.180	10.0	7.00	0.000	1.00	120.	1.00
1	1.0	3.30	0.570	15.0	3.00	0.000	1.00	120.	1.00
1	1.0	1.60	0.630	15.0	3.00	0.000	1.00	120.	1.00
1	1.0	1.75	0.700	15.0	3.00	0.000	1.00	120.	1.00
1	0.0	4.70	0.710	15.0	3.00	0.000	1.00	120.	1.00
1	1.0	1.10	0.650	15.0	3.00	0.000	1.00	120.	1.00
1	1.0	1.75	0.470	10.0	10.0	0.000	1.00	120.	1.00
1	0.0	2.75	0.550	10.0	10.0	0.000	1.00	120	1.00
1	1.0	0.650	0.580	10.0	10.0	0.000	1.00	120.	1.00
1	1.0	1.85	0.130	15.0	3.00	0.000	1.00	145.	1.00
1	0.0	5.80	0.170	15.0	3.00	0.000	1.00	145.	1.00
1	1.0	1.80	0.250	15.0	3.00	0.000	1.00	145.	1.00
1	0.0	2.80	0.250	15.0	3.00	0.000	1.00	145.	1.00
1	0.0	3.90	0.300	15.0	3.00	0.000	1.00	145.	1.00
1	1.0	0.750	0.330	15.0	3.00	0.000	1.00	145.	1.00
1	0.0	4.20	0.730	15.0	3.00	0.000	1.00	120.	1.00
1	1.0	1.05	0.780	15.0	3.00	0.000	1.00	120.	1.00
1	1.0	1.60	0.820	15.0	3.00	0.000	1.00	120.	1.00
1	1.0	2.70	0.880	15.0	3.00	0.000	1.00	120.	1.00
1	1.0	3.20	0.770	15.0	3.00	0.000	1.00	120.	1.00
1	0.0	4.70	0.700	15.0	3.00	0.000	1.00	120.	1.00
1	0.0	4.00	0.830	15.0	3.00	0.000	1.00	120.	1.00
1	1.0	0.700	0.830	15.0	3.00	0.000	1.00	120.	1.00
1	1.0	1.65	0.030	15.0	1.00	0.000	1.00	143.	1.00
1	0.0	5.50	0.080	15.0	1.00	0.000	1.00	143.	1.00
1	1.0	2.55	0.080	15.0	1.00	0.000	1.00	143.	1.00
1	1.0	1.25	0.100	15.0	1.00	0.000	1.00	143.	1.00
1	1.0	1.00	0.130	15.0	1.00	0.000	1.00	143.	1.00
1	0.0	1.90	0.150	15.0	3.00	0.000	1.00	143.	1.00
1	1.0	2.10	0.220	15.0	1.00	0.000	1.00	143.	1.00
1	0.0	5.70	0.260	15.0	1.00	0.000	1.00	143.	1.00
1	1.0	1.60	0.300	15.0	1.00	0.000	1.00	143.	1.00
1	1.0	4.40	0.330	15.0	1.00	0.000	1.00	143.	1.00
1	0.0	2.65	0.430	15.0	1.00	0.000	1.00	145.	1.00
1	1.0	3.60	0.530	15.0	1.00	0.000	1.00	145.	1.00
1	1.0	1.10	0.570	15.0	1.00	0.000	1.00	145.	1.00
1	1.0	3.90	0.500	15.0	1.00	0.000	1.00	145.	1.00
1	1.0	0.100	0.450	15.0	1.00	0.000	1.00	145.	1.00
1	0.0	6.90	0.520	15.0	1.00	0.000	1.00	145.	1.00
1	0.0	3.60	0.530	15.0	1.00	0.000	1.00	145	1.00

TABLE A-1. UNSORTED INPUT DATA (CONT.)

OBSVN	SUCCESS(1) FAILURE(0)	LATR	EXPLANATORY VARIABLES FATO	VIS	WDSP	CLDC	SWLL	SPED	UNIT
1	0.0	5.00	0.630	15.0	1.00	0.000	1.00	145.	1.00
1	1.0	0.100	0.650	15.0	1.00	0.000	1.00	145.	1.00
1	0.0	3.60	0.100	15.0	3.00	0.000	2.00	150.	-1.00
1	0.0	3.60	0.130	15.0	3.00	0.000	2.00	150.	-1.00
1	1.0	0.400	0.150	15.0	3.00	0.000	2.00	150.	-1.00
1	1.0	1.10	0.200	15.0	3.00	0.000	2.00	150.	-1.00
1	0.0	3.60	0.230	15.0	3.00	0.000	2.00	150.	-1.00
1	0.0	4.10	0.250	15.0	3.00	0.000	2.00	150.	-1.00
1	0.0	2.60	0.100	8.00	10.0	0.000	1.50	150.	-1.00
1	0.0	1.00	0.130	8.00	10.0	0.000	1.50	150.	-1.00
1	0.0	0.900	0.150	8.00	10.0	0.000	1.50	150.	-1.00
1	0.0	1.10	0.160	8.00	10.0	0.000	1.50	150.	-1.00
1	0.0	2.80	0.170	8.00	10.0	0.000	1.50	150.	-1.00
1	1.0	1.00	0.200	8.00	10.0	0.000	1.50	150.	-1.00
1	1.0	0.800	0.250	8.00	10.0	0.000	1.50	150.	-1.00
1	0.0	1.10	0.280	8.00	10.0	0.000	1.50	150.	-1.00
1	0.0	4.00	0.310	8.00	10.0	0.000	1.50	150.	-1.00
1	1.0	0.800	0.350	8.00	10.0	0.000	1.50	150.	-1.00
1	0.0	3.40	3.20	8.00	12.0	0.000	3.00	150.	-1.00
1	1.0	0.350	3.25	8.00	12.0	0.000	3.00	150.	-1.00
1	0.0	3.30	3.28	8.00	12.0	0.000	3.00	150.	-1.00
1	0.0	1.40	3.30	8.00	12.0	0.000	3.00	150.	-1.00
1	0.0	0.500	3.38	8.00	12.0	0.000	3.00	150.	-1.00
1	0.0	1.40	3.40	8.00	12.0	0.000	3.00	150.	-1.00
1	0.0	4.70	3.33	8.00	12.0	0.000	3.00	150.	-1.00
1	0.0	2.90	3.42	8.00	12.0	0.000	3.00	150.	-1.00
1	1.0	0.500	3.45	8.00	12.0	0.000	3.00	150.	-1.00
1	0.0	2.20	3.48	8.00	12.0	0.000	3.00	150.	-1.00
1	0.0	2.00	0.080	8.00	10.0	0.000	1.50	150.	-1.00
1	0.0	0.100	0.120	8.00	10.0	0.000	1.50	150.	-1.00
1	1.0	1.20	0.150	8.00	10.0	0.000	1.50	150.	-1.00
1	0.0	2.20	0.330	8.00	10.0	0.000	1.50	150.	-1.00
1	0.0	0.500	0.220	8.00	10.0	0.000	1.50	150.	-1.00
1	1.0	0.200	0.230	8.00	10.0	0.000	1.50	150.	-1.00
1	0.0	2.10	0.160	8.00	10.0	0.000	1.50	150.	-1.00
1	0.0	1.80	0.100	8.00	12.0	0.000	3.00	150.	-1.00
1	0.0	0.000	0.140	8.00	12.0	0.000	3.00	150.	-1.00
1	0.0	3.35	0.160	8.00	12.0	0.000	3.00	150.	-1.00
1	0.0	2.30	0.170	8.00	12.0	0.000	3.00	150.	-1.00
1	1.0	1.10	0.180	8.00	12.0	0.000	3.00	150.	-1.00
1	0.0	0.750	0.230	8.00	12.0	0.000	3.00	150.	-1.00
1	0.0	2.65	0.260	8.00	12.0	0.000	3.00	150.	-1.00
1	0.0	2.40	0.220	8.00	12.0	0.000	3.00	150.	-1.00
1	1.0	0.300	0.300	8.00	12.0	0.000	3.00	150.	-1.00
1	1.0	0.400	0.100	5.00	5.00	0.800	1.00	200.	-1.00
1	0.0	1.70	0.200	5.00	5.00	0.800	1.00	200.	-1.00
1	0.0	2.00	0.200	5.00	5.00	0.800	1.00	200.	-1.00

TABLE A-1. UNSORTED INPUT DATA (CONT.)

OBSVN	SUCCESS(1) FAILURE(0)	EXPLANATORY VARIABLES LATR	FATO	VIS	WDSP	CLDC	SWLL	SPED	UNIT
1	0.0	0.150	0.250	5.00	5.00	0.800	1.00	200.	-1.00
1	0.0	1.60	0.320	5.00	5.00	0.800	1.00	200.	-1.00
1	0.0	2.35	0.680	5.00	5.00	0.800	1.00	150.	-1.00
1	0.0	1.60	0.560	5.00	5.00	0.800	1.00	150.	-1.00
1	0.0	0.550	0.660	5.00	5.00	0.800	1.00	150.	-1.00
1	0.0	0.700	0.600	5.00	5.00	0.800	1.00	150.	-1.00
1	1.0	1.10	0.620	5.00	5.00	0.800	1.00	150.	-1.00
1	0.0	2.15	0.580	5.00	5.00	0.800	1.00	150.	-1.00
1	0.0	0.750	0.600	8.00	7.00	0.700	1.50	150.	-1.00
1	1.0	0.100	0.750	8.00	7.00	0.700	1.50	150.	-1.00
1	0.0	0.500	0.830	8.00	7.00	0.700	1.50	150.	-1.00
1	0.0	0.800	0.880	8.00	7.00	0.700	1.50	150.	-1.00
1	1.0	1.80	0.180	8.00	7.00	0.700	1.50	200.	-1.00
1	0.0	0.700	0.230	8.00	7.00	0.700	1.50	200.	-1.00
1	0.0	0.000	0.250	8.00	7.00	0.700	1.50	200	-1.00
1	1.0	0.300	0.250	8.00	7.00	0.700	1.50	200.	-1.00

SIMPLE STATISTICS

	#OBSN	SS/TOT	LATR	FATO	VIS	WDSP	CLDC	SWLL	SPED	UNIT
MEANS	111.	0.42	2.02	0.626	10.9	6.20	0.130	1.53	147.	

TABLE A-2. INITIAL LOGODDS MODEL FIT

A SOLUTION WAS REACHED AFTER 5 ITERATIONS

THE 90 PERCENT CONFIDENCE LIMITS

PARAMETER		FINAL ESTIMATE	LOWER LIMIT	UPPER LIMIT	SIGNIFICANT VARIABLE
	A(0)	0. 7750555099D 1	-0. 6577411372D 0	0. 1615885134D 2	
LATR	A(1)	-0. 1732310944D 1	-0. 2318596843D 1	-0. 1146025045D 1	YE
FATG	A(2)	0. 1235656477D 0	-0. 5612656701D 0	0. 8083969658D 0	NO
VIS	A(3)	-0. 8639872618D -1	-0. 5412142609D 0	0. 3684168085D 0	NO
WDSP	A(4)	-0. 3921415905D 0	-0. 8005320188D 0	0. 1624883768D -1	NO
CLDC	A(5)	-0. 3104179485D 1	-0. 6553545460D 1	0. 3451864897D 0	NO
SWLL	A(6)	0. 1335304133D 6	-0. 1317394597D 1	0. 1584455424D 1	NO
SPED	A(7)	-0. 7785789574D -2	-0. 4109614970D -1	0. 2552457055D -1	NO
UNIT	A(8)	0. 1040815960D 1	-0. 1184645917D 0	0. 2200096511D 1	NO

ALPHA LEVEL CORRESPONDING TO THE SIGNIFICANCE OF ALL EXPLANATORY VARIABLES (EXCEPT Y(0)) = . 5960465762D -7

VARIANCE-COVARIANCE MATRIX FOR THE PARAMETERS

A(0)	0. 26119967D 2	-0. 50323984D 0	-0. 30554455D 0	-0. 10682065D 1	-0. 10118641D 1	-0. 57083176D 1	0. 17160644D 1	-0. 59237497D -1	0. 48034810D 0
A(1)	-0. 50323984D 0	0. 12699175D 0	-0. 87995899D -2	0. 35666718D -2	0. 26207146D -1	0. 17390301D 0	-0. 16761950D -1	0. 44995453D -3	-0. 56327348D -1
A(2)	-0. 30554455D 0	-0. 87995899D -2	0. 17327019D 0	0. 16590100D -1	0. 10538419D -1	-0. 10621440D 0	-0. 20315722D 0	0. 19197857D -2	-0. 59887800D -1
A(3)	-0. 10682065D 1	0. 35666718D -2	0. 16590100D -1	0. 76423549D -1	0. 54585046D -1	0. 40093477D 0	-0. 12360844D 0	0. 89649132D -5	-0. 96637204D -1
A(4)	-0. 10118641D 1	0. 26207146D -1	0. 10538419D -1	0. 54585046D -1	0. 61618019D -1	0. 36592126D 0	-0. 12187543D 0	0. 70217825D -3	-0. 30545818D -1
A(5)	-0. 57083176D 1	0. 17390301D 0	-0. 10621440D 0	0. 40093477D 0	0. 36592126D 0	0. 43957721D 1	-0. 12428609D 0	-0. 11184865D -1	-0. 11849609D 0
A(6)	0. 17160644D 1	-0. 16761950D -1	-0. 20315722D 0	-0. 12360844D 0	-0. 12187543D 0	-0. 12428609D 0	0. 77775170D 0	-0. 38334625D -2	0. 30244655D 0
A(7)	-0. 59237497D -1	0. 44995453D -3	0. 19197857D -2	0. 89649132D -5	0. 70217825D -3	-0. 11184865D -1	-0. 38334625D -2	0. 40993526D -3	0. 34731274D -2
A(8)	0. 48034810D 0	-0. 56327348D -1	-0. 59887800D -1	-0. 96637204D -1	-0. 30545818D -1	-0. 11849609D 0	0. 30244655D 0	0. 34731274D -2	0. 49651654D 0

-2 LN LIKELIHOOD = 83. 75196596

TABLE A-3. LOGODDS MODEL FIT AFTER ELIMINATING VARIABLE CLOUD COVER

(RESULTS OBTAINED BY OMITTING EXPLANATORY VARIABLE Y(5)

A SOLUTION WAS REACHED AFTER 5 ITERATIONS

THE 90 PERCENT CONFIDENCE LIMITS

	PARAMETER	FINAL ESTIMATE	LOWER LIMIT	UPPER LIMIT	SIGNIFICANT VARIABLE
	A(0)	0.3866035110D 1	-0.2980194417D 1	0.1071226464D 2	
LATR	A(1)	-0.1633855160D 1	-0.2186796370D 1	-0.1080913949D 1	YE
FAIG	A(2)	0.4399544874D -1	-0.6295043178D 0	0.7174952153D 0	NO
VIS	A(3)	0.1954555019D 0	-0.1285760455D 0	0.5194870494D 0	NO
WDSP	A(4)	-0.1397746012D 0	-0.4263854427D 0	0.1468362402D 0	NO
SWLL	A(5)	0.7112007545D -1	-0.1362051273D 1	0.1504291424D 1	NO
SPED	A(6)	-0.1630686884D -1	-0.4732122128D -1	0.1470748361D -1	NO
UNIT	A(7)	0.9826848584D 0	-0.1465536720D 0	0.2111923389D 1	NO

ALPHA LEVEL CORRESPONDING TO THE SIGNIFICANCE OF ALL EXPLANATORY VARIABLES (EXCEPT Y(0)) = .5960465762D -7

VARIANCE-COVARIANCE MATRIX FOR THE PARAMETERS

A(0)	0.17316477D 2	-0.25203468D 0	-0.42615358D 0	-0.51620022D 0	-0.50425008D 0	0.14806327D 1	-0.67716277D -1	0.32392043D 0
A(1)	-0.25203468D 0	0.11295736D 0	-0.52357231D -2	-0.12040531D -1	0.94242952D -2	-0.85400016D -2	0.88111999D -3	-0.48422036D -1
A(2)	-0.42615358D 0	-0.52357231D -2	0.16758360D 0	0.25054032D -1	0.18262369D -1	-0.19456582D 0	0.15899319D -2	-0.57531087D -1
A(3)	-0.51620022D 0	-0.12040531D -1	0.25054032D -1	0.38791021D -1	0.21447316D -1	-0.11133860D 0	0.87674533D -3	-0.83827516D -1
A(4)	-0.50425008D 0	0.94242952D -2	0.18262369D -1	0.21447316D -1	0.30348823D -1	-0.11034532D 0	0.14590206D -2	-0.23214734D -1
A(5)	0.14806327D 1	-0.85400016D -2	-0.19456582D 0	-0.11133860D 0	-0.11034532D 0	0.75884461D 0	-0.37426370D -2	0.29752403D 0
A(6)	-0.67716277D -1	0.88111999D -3	0.15899319D -2	0.87674533D -3	0.14590206D -2	-0.37426370D -2	0.35537106D -3	0.30645370D -2
A(7)	0.32392043D 0	-0.48422036D -1	-0.57531087D -1	-0.83827516D -1	-0.23214734D -1	0.29752403D 0	0.30645370D -2	0.47111616D 0

-2 LN LIKELIHOOD = 86.06217715

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ANALYSIS OF VISUAL DETECTION PERFORMANCE (FALL 1978 EXPERIMENT)--ETC(U)
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TABLE A-4. LOGODDS MODEL FIT AFTER ELIMINATING VARIABLE SWELL

RESULTS OBTAINED BY OMITTING EXPLANATORY VARIABLE Y(5)

A SOLUTION WAS REACHED AFTER 4 ITERATIONS

THE 90 PERCENT CONFIDENCE LIMITS

	PARAMETER	FINAL ESTIMATE	LOWER LIMIT	UPPER LIMIT	SIGNIFICANT VARIABLE
	A(0)	0.37276282660 1	-0.25262080180 1	0.99814645490 1	
LATR	A(1)	-0.16331677600 1	-0.21861689730 1	-0.10801665480 1	YE
FATG	A(2)	0.62303222730 -1	-0.50227766100 0	0.62886410840 0	NO
VIS	A(3)	0.20589091390 0	-0.40758165210 -1	0.45253999300 0	NO
WDSP	A(4)	-0.12946483850 0	-0.32658021700 0	0.67650540060 -1	NO
SPED	A(5)	-0.15956375110 -1	-0.46154170200 -1	0.14241419980 -1	NO
UNIT	A(6)	0.95489383640 0	-0.24571602360 -1	0.19343592750 1	NO

ALPHA LEVEL CORRESPONDING TO THE SIGNIFICANCE OF ALL EXPLANATORY VARIABLES (EXCEPT Y(0)) = .59604657620 -7

VARIANCE-COVARIANCE MATRIX FOR THE PARAMETERS

A(0)	0.14449394D 2	-0.23597523D 0	-0.44979791D -1	-0.29984101D 0	-0.29009351D 0	-0.60450165D -1	-0.25684500D 0
A(1)	-0.23597523D 0	0.11298188D 0	-0.75639002D -2	-0.13262467D -1	0.81969754D -2	0.84004113D -3	-0.45299662D -1
A(2)	-0.44979791D -1	-0.75639002D -2	0.11776303D 0	-0.35139783D -2	-0.10092712D -1	0.62567727D -3	0.18755907D -1
A(3)	-0.29984101D 0	-0.13262467D -1	-0.35139783D -2	0.22475824D -1	0.53007374D -2	0.32980637D -3	-0.40107262D -1
A(4)	-0.29009351D 0	0.81969754D -2	-0.10092712D -1	0.53007374D -2	0.14354816D -1	0.91739283D -3	0.20057212D -1
A(5)	-0.60450165D -1	0.84004113D -3	0.62567727D -3	0.32980637D -3	0.91739283D -3	0.33890471D -3	0.45310151D -2
A(6)	-0.25684500D 0	-0.45299662D -1	0.18755907D -1	-0.40107262D -1	0.20057212D -1	0.45310151D -2	0.35443357D 0

-2 LN LIKELIHOOD = 86.06883003

TABLE A-5. LOGODDS MODEL FIT AFTER ELIMINATING VARIABLE UNIT

RESULTS OBTAINED BY OMITTING EXPLANATORY VARIABLE Y(6)

A SOLUTION WAS REACHED AFTER 5 ITERATIONS

THE 90 PERCENT CONFIDENCE LIMITS

	PARAMETER	FINAL ESTIMATE	LOWER LIMIT	UPPER LIMIT	SIGNIFICANT VARIABLE
	A(0)	0.4902984371D 1	-0.1120740403D 1	0.1092670914D 2	
LATR	A(1)	-0.1601099094D 1	-0.2141498678D 1	-0.1060599510D 1	YE
FATG	A(2)	0.1774685500D -1	-0.5394900906D 0	0.5749838006D 0	NO
VIS	A(3)	0.3226071328D 0	0.1014457620D 0	0.5437685036D 0	YE
WDSP	A(4)	-0.1929537593D 0	-0.3799109714D 0	-0.5996547169D -2	YE
SPED	A(5)	-0.3068734495D -1	-0.5783530513D -1	-0.3539384771D -2	YE

ALPHA LEVEL CORRESPONDING TO THE SIGNIFICANCE OF ALL EXPLANATORY VARIABLES (EXCEPT Y(0)) = .5960465762D -7

VARIANCE-COVARIANCE MATRIX FOR THE PARAMETERS

A(0)	0.134056619D 2	-0.206787771D 0	-0.267959140 -1	-0.313222080 0	-0.257361520 0	-0.541226300 -1
A(1)	-0.206787771D 0	0.107891350 0	-0.539769050 -2	-0.205074080 -1	0.104253810 -1	0.114574210 -2
A(2)	-0.267959140 -1	-0.539769050 -2	0.114719280 0	-0.116421500 -2	-0.106619410 -1	0.344063040 -3
A(3)	-0.313222080 0	-0.205074080 -1	-0.116421500 -2	0.180707080 -1	0.727940400 -2	0.762592730 -3
A(4)	-0.257361520 0	0.104253810 -1	-0.106619410 -1	0.727940400 -2	0.129134140 -1	0.570202060 -3
A(5)	-0.541226300 -1	0.114574210 -2	0.344063040 -3	0.762592730 -3	0.570202060 -3	0.272289580 -3

-2 LN LIKELIHOOD = 88.90815498

TABLE A-6. LOGODDS MODEL FIT AFTER ELIMINATING VARIABLE FATG

RESULTS OBTAINED BY OMITTING EXPLANATORY VARIABLE Y(2)

A SOLUTION WAS REACHED AFTER 3 ITERATIONS

THE 90 PERCENT CONFIDENCE LIMITS

	PARAMETER	FINAL ESTIMATE	LOWER LIMIT	UPPER LIMIT	SIGNIFICANT VARIABLE
	A(0)	0.4907358412D 1	-0.1116058984D 1	0.1093077581D 2	
LATR	A(1)	-0.1600301705D 1	-0.2140054891D 1	-0.1060548519D 1	YE
VIS	A(2)	0.3227893298D 0	0.1016470343D 0	0.5439316254D 0	YE
WDSP	A(3)	-0.1913198046D 0	-0.3710568483D 0	-0.1158076094D -1	YE
SPED	A(4)	-0.3074129411D -1	-0.5783615379D -1	-0.3646434432D -2	YE

ALPHA LEVEL CORRESPONDING TO THE SIGNIFICANCE OF ALL EXPLANATORY VARIABLES (EXCEPT Y(0)) = .5960465762D -7

VARIANCE-COVARIANCE MATRIX FOR THE PARAMETERS

A(0)	0.13404251D 2	-0.20791313D 0	-0.31374468D 0	-0.26012055D 0	-0.54046251D -1
A(1)	-0.20791313D 0	0.10763340D 0	-0.20563347D -1	0.99118883D -2	0 11616462D -2
A(2)	-0.31374468D 0	-0.20563347D -1	0.18067591D -1	0.71843516D -2	0.76657314D -3
A(3)	-0.26012055D 0	0.99118883D -2	0.71843516D -2	0.11935524D -1	0.60265851D -3
A(4)	-0.54046251D -1	0.11616462D -2	0.76657314D -3	0.60265851D -3	0.27122545D -3

-2 LN LIKELIHOOD = 88.91090157

TABLE A-7. LOGODDS MODEL ESTIMATES OF PROBABILITY OF DETECTION SORTED BY LATERAL RANGE

FITTED	CONFIDENCE BOUNDS			EXPLANATORY VARIABLES		
PROBABILITY	LOWER	UPPER	LATR	VIS	WDSP	SPED
0.64168	0.42329	0.81375	0.0000	8.000	12.00	150.0
0.50054	0.20852	0.79219	0.0000	8.000	7.000	200.0
0.99290	0.95735	0.99885	0.1000	15.00	1.000	145.0
0.69110	0.51782	0.82335	0.1000	8.000	10.00	150.0
0.98239	0.91392	0.99660	0.1000	15.00	5.000	150.0
0.79886	0.63270	0.90155	0.1000	8.000	7.000	150.0
0.99290	0.95735	0.99885	0.1000	15.00	1.000	145.0
0.30500	0.09651	0.64323	0.1500	5.000	5.000	200.0
0.65593	0.48564	0.79379	0.2000	8.000	10.00	150.0
0.52562	0.32520	0.71811	0.3000	8.000	12.00	150.0
0.38274	0.14426	0.69520	0.3000	8.000	7.000	200.0
0.50563	0.30943	0.70011	0.3500	8.000	12.00	150.0
0.98062	0.91408	0.99586	0.4000	15.00	3.000	150.0
0.22729	0.06679	0.54728	0.4000	5.000	5.000	200.0
0.54119	0.38636	0.68845	0.5000	8.000	10.00	150.0
0.67680	0.50996	0.80819	0.5000	8.000	7.000	150.0
0.44584	0.26383	0.64363	0.5000	8.000	12.00	150.0
0.96447	0.86338	0.99150	0.5500	15.00	5.000	150.0
0.51833	0.22140	0.80285	0.5500	5.000	5.000	150.0
0.89538	0.73597	0.96334	0.6000	10.00	7.000	120.0
0.81651	0.61035	0.92670	0.6500	10.00	10.00	120.0
0.24638	0.08269	0.54247	0.7000	8.000	7.000	200.0
0.98746	0.94085	0.99744	0.7000	15.00	3.000	120.0
0.45842	0.18369	0.76100	0.7000	5.000	5.000	150.0
0.58395	0.42607	0.72630	0.7500	8.000	7.000	150.0
0.35033	0.19526	0.54513	0.7500	8.000	12.00	150.0
0.97118	0.89282	0.99272	0.7500	15.00	3.000	145.0
0.42190	0.28825	0.56807	0.8000	8.000	10.00	150.0
0.56439	0.40897	0.70811	0.8000	8.000	7.000	150.0
0.38344	0.25722	0.52759	0.9000	8.000	10.00	150.0
0.97239	0.89520	0.99316	1.000	15.00	1.000	143.0
0.34637	0.22759	0.48798	1.000	8.000	10.00	150.0
0.97825	0.91405	0.99477	1.050	15.00	3.000	120.0
0.96578	0.87804	0.99104	1.100	15.00	1.000	145.0
0.31109	0.19967	0.44974	1.100	8.000	10.00	150.0
0.97648	0.90938	0.99421	1.100	15.00	3.000	120.0
0.31109	0.19967	0.44974	1.100	8.000	10.00	150.0
0.94288	0.82595	0.98238	1.100	15.00	3.000	150.0
0.23547	0.11920	0.41209	1.100	8.000	12.00	150.0
0.30857	0.10529	0.62858	1.100	5.000	5.000	150.0
0.27786	0.17371	0.41324	1.200	8.000	10.00	150.0
0.95936	0.86458	0.98867	1.250	15.00	1.000	143.0
0.16006	0.07357	0.31378	1.400	8.000	12.00	150.0
0.68711	0.46979	0.84478	1.450	10.00	7.000	120.0
0.64074	0.42245	0.81304	1.580	10.00	7.000	120.0
0.94911	0.84730	0.98430	1.600	15.00	3.000	120.0
0.93095	0.80800	0.97737	1.600	15.00	1.000	143.0
0.04133	0.00877	0.17366	1.600	5.000	5.000	200.0
0.16701	0.04752	0.44621	1.600	5.000	5.000	150.0
0.92563	0.79842	0.97507	1.650	15.00	1.000	143.0
0.03543	0.00729	0.15516	1.700	5.000	5.000	200.0
0.43354	0.23662	0.65395	1.750	10.00	10.00	120.0
0.93618	0.82212	0.97897	1.750	15.00	3.000	120.0
0.86262	0.70590	0.94261	1.800	15.00	3.000	145.0
0.09130	0.03621	0.21177	1.800	8.000	12.00	150.0
0.05323	0.01330	0.18998	1.800	8.000	7.000	200.0

TABLE A-7. LOGODDS MODEL ESTIMATES OF PROBABILITY OF DETECTION SORTED BY LATERAL RANGE (CONT.)

FITTED	CONFIDENCE BOUNDS			EXPLANATORY VARIABLES		
PROBABILITY	LOWER	UPPER	LATR	VIS	WDSP	SPED
0. 85286	0. 69271	0. 93712	1. 850	15. 00	3. 000	145. 0
0. 85052	0. 69300	0. 93482	1. 900	15. 00	3. 000	143. 0
0. 09662	0. 04473	0. 19634	2. 000	8. 000	10. 00	150. 0
0. 02222	0. 00416	0. 10997	2. 000	5. 000	5. 000	200. 0
0. 85830	0. 69310	0. 94202	2. 100	15. 00	1. 000	143. 0
0. 08353	0. 03696	0. 17793	2. 100	8. 000	10. 00	150. 0
0. 07677	0. 01806	0. 27325	2. 150	5. 000	5. 000	150. 0
0. 05031	0. 01693	0. 14008	2. 200	8. 000	12. 00	150. 0
0. 07207	0. 03045	0. 16111	2. 200	8. 000	10. 00	150. 0
0. 04319	0. 01393	0. 12608	2. 300	8. 000	12. 00	150. 0
0. 05694	0. 01248	0. 22382	2. 350	5. 000	5. 000	150. 0
0. 03704	0. 01143	0. 11342	2. 400	8. 000	12. 00	150. 0
0. 74670	0. 55301	0. 87538	2. 550	15. 00	1. 000	143. 0
0. 03934	0. 01373	0. 10752	2. 600	8. 000	10. 00	150. 0
0. 02513	0. 00694	0. 08687	2. 650	8. 000	12. 00	150. 0
0. 70258	0. 50229	0. 84684	2. 650	15. 00	1. 000	145. 0
0. 76233	0. 57012	0. 88580	2. 700	15. 00	3. 000	120. 0
0. 13380	0. 04954	0. 31406	2. 750	10. 00	10. 00	120. 0
0. 44536	0. 25188	0. 65696	2. 750	15. 00	5. 000	150. 0
0. 55895	0. 37764	0. 72580	2. 800	15. 00	3. 000	145. 0
0. 02887	0. 00913	0. 08753	2. 800	8. 000	10. 00	150. 0
0. 01699	0. 00418	0. 06640	2. 900	8. 000	12. 00	150. 0
0. 11775	0. 04173	0. 29033	3. 200	10. 00	7. 000	120. 0
0. 59033	0. 38437	0. 76882	3. 200	15. 00	3. 000	120. 0
0. 55114	0. 34708	0. 73933	3. 300	15. 00	3. 000	120. 0
0. 00903	0. 00184	0. 04308	3. 300	8. 000	12. 00	150. 0
0. 00834	0. 00166	0. 04081	3. 350	8. 000	12. 00	150. 0
0. 00770	0. 00150	0. 03865	3. 400	8. 000	12. 00	150. 0
0. 22104	0. 09945	0. 42169	3. 400	15. 00	5. 000	150. 0
0. 19472	0. 08427	0. 38852	3. 500	15. 00	5. 000	150. 0
0. 34058	0. 18152	0. 54604	3. 600	15. 00	1. 000	145. 0
0. 23200	0. 11278	0. 41791	3. 600	15. 00	3. 000	150. 0
0. 34058	0. 18152	0. 54604	3. 600	15. 00	1. 000	145. 0
0. 24218	0. 11436	0. 44163	3. 900	15. 00	1. 000	145. 0
0. 17896	0. 08204	0. 34708	3. 900	15. 00	3. 000	145. 0
0. 00434	0. 00075	0. 02476	4. 000	8. 000	10. 00	150. 0
0. 28599	0. 13591	0. 50496	4. 000	15. 00	3. 000	120. 0
0. 11950	0. 04498	0. 27199	4. 100	15. 00	3. 000	150. 0
0. 22531	0. 09773	0. 43850	4. 200	15. 00	3. 000	120. 0
0. 13245	0. 05097	0. 30263	4. 400	15. 00	1. 000	143. 0
0. 00097	0. 00010	0. 00942	4. 700	8. 000	12. 00	150. 0
0. 11556	0. 03957	0. 29299	4. 700	15. 00	3. 000	120. 0
0. 05210	0. 01492	0. 16625	5. 000	15. 00	1. 000	145. 0
0. 02559	0. 00585	0. 10489	5. 500	15. 00	1. 000	143. 0
0. 01871	0. 00388	0. 08534	5. 700	15. 00	1. 000	143. 0
0. 01031	0. 00190	0. 05398	5. 800	15. 00	3. 000	145. 0
0. 00262	0. 00030	0. 02281	6. 900	15. 00	1. 000	145. 0

TABLE A-8. LOGODDS PLOTS

FITTED	CONFIDENCE BOUNDS			EXPLANATORY VARIABLES		
PROBABILITY	LOWER	UPPER	LATR	VIS	WDSP	SPED
0. 89485	0. 62707	0. 97731	0. 2625	7. 000	5. 000	120. 0
0. 85084	0. 54293	0. 96478	0. 5125	7. 000	5. 000	120. 0
0. 79267	0. 45375	0. 94623	0. 7625	7. 000	5. 000	120. 0
0. 71931	0. 36488	0. 91955	1. 013	7. 000	5. 000	120. 0
0. 63204	0. 28198	0. 88253	1. 262	7. 000	5. 000	120. 0
0. 53517	0. 20962	0. 83328	1. 512	7. 000	5. 000	120. 0
0. 43557	0. 15030	0. 77098	1. 762	7. 000	5. 000	120. 0
0. 34091	0. 10438	0. 69656	2. 012	7. 000	5. 000	120. 0
0. 25744	0. 07053	0. 61299	2. 262	7. 000	5. 000	120. 0
0. 18856	0. 04659	0. 52498	2. 512	7. 000	5. 000	120. 0
0. 13477	0. 03020	0. 43793	2. 762	7. 000	5. 000	120. 0
0. 09453	0. 01928	0. 35670	3. 012	7. 000	5. 000	120. 0
0. 06540	0. 01216	0. 28466	3. 262	7. 000	5. 000	120. 0
0. 04480	0. 00759	0. 22345	3. 512	7. 000	5. 000	120. 0
0. 03048	0. 00470	0. 17317	3. 762	7. 000	5. 000	120. 0
0. 02064	0. 00289	0. 13293	4. 012	7. 000	5. 000	120. 0
0. 01393	0. 00177	0. 10137	4. 262	7. 000	5. 000	120. 0
0. 00938	0. 00107	0. 07694	4. 512	7. 000	5. 000	120. 0
0. 00631	0. 00065	0. 05823	4. 762	7. 000	5. 000	120. 0
0. 00424	0. 00039	0. 04400	5. 012	7. 000	5. 000	120. 0
0. 00284	0. 00024	0. 03321	5. 262	7. 000	5. 000	120. 0
0. 00191	0. 00014	0. 02506	5. 512	7. 000	5. 000	120. 0
0. 00128	0. 00009	0. 01892	5. 762	7. 000	5. 000	120. 0
0. 00086	0. 00005	0. 01428	6. 012	7. 000	5. 000	120. 0
0. 00058	0. 00003	0. 01079	6. 262	7. 000	5. 000	120. 0
0. 00039	0. 00002	0. 00816	6. 512	7. 000	5. 000	120. 0
0. 00026	0. 00001	0. 00617	6. 762	7. 000	5. 000	120. 0
0. 00017	0. 00000	0. 00467	7. 012	7. 000	5. 000	120. 0

AREA UNDER FITTED PROBABILITY FOR VARIABLE 1

UPPER	FITTED	LOWER
2. 6452	1. 6237	0. 81088

FITTED	CONFIDENCE BOUNDS			EXPLANATORY VARIABLES		
PROBABILITY	LOWER	UPPER	LATR	VIS	WDSP	SPED
0. 94055	0. 80252	0. 98402	0. 2625	10. 00	2. 000	150. 0
0. 91383	0. 74933	0. 97411	0. 5125	10. 00	2. 000	150. 0
0. 87666	0. 68565	0. 95861	0. 7625	10. 00	2. 000	150. 0
0. 82651	0. 61176	0. 93508	1. 013	10. 00	2. 000	150. 0
0. 76152	0. 52932	0. 90067	1. 262	10. 00	2. 000	150. 0
0. 68157	0. 44169	0. 85274	1. 512	10. 00	2. 000	150. 0
0. 58926	0. 35374	0. 78993	1. 762	10. 00	2. 000	150. 0
0. 49021	0. 27106	0. 71320	2. 012	10. 00	2. 000	150. 0
0. 39193	0. 19862	0. 62633	2. 262	10. 00	2. 000	150. 0
0. 30168	0. 13951	0. 53513	2. 512	10. 00	2. 000	150. 0
0. 22455	0. 09439	0. 44582	2. 762	10. 00	2. 000	150. 0
0. 16254	0. 06190	0. 36342	3. 012	10. 00	2. 000	150. 0
0. 11512	0. 03960	0. 29102	3. 262	10. 00	2. 000	150. 0
0. 08020	0. 02485	0. 22979	3. 512	10. 00	2. 000	150. 0
0. 05522	0. 01537	0. 17951	3. 762	10. 00	2. 000	150. 0
0. 03770	0. 00941	0. 13911	4. 012	10. 00	2. 000	150. 0
0. 02559	0. 00571	0. 10717	4. 262	10. 00	2. 000	150. 0
0. 01730	0. 00345	0. 08223	4. 512	10. 00	2. 000	150. 0
0. 01166	0. 00207	0. 06290	4. 762	10. 00	2. 000	150. 0
0. 00785	0. 00124	0. 04803	5. 012	10. 00	2. 000	150. 0
0. 00527	0. 00074	0. 03662	5. 262	10. 00	2. 000	150. 0
0. 00354	0. 00044	0. 02791	5. 512	10. 00	2. 000	150. 0
0. 00238	0. 00026	0. 02126	5. 762	10. 00	2. 000	150. 0
0. 00159	0. 00015	0. 01619	6. 012	10. 00	2. 000	150. 0
0. 00107	0. 00009	0. 01233	6. 262	10. 00	2. 000	150. 0
0. 00072	0. 00005	0. 00939	6. 512	10. 00	2. 000	150. 0
0. 00048	0. 00003	0. 00716	6. 762	10. 00	2. 000	150. 0
0. 00032	0. 00002	0. 00545	7. 012	10. 00	2. 000	150. 0

AREA UNDER FITTED PROBABILITY FOR VARIABLE 1

UPPER	FITTED	LOWER
2. 6995	1. 9893	1. 3551

TABLE A-8. LOGODDS PLOTS (CONT.)

FITTED	CONFIDENCE BOUNDS			EXPLANATORY VARIABLES		
PROBABILITY	LOWER	UPPER	LATR	VIS	WDSP	SPED
0.94505	0.73348	0.99078	0.2625	15.00	10.00	150.0
0.92017	0.66580	0.98523	0.5125	15.00	10.00	150.0
0.88540	0.58875	0.97658	0.7625	15.00	10.00	150.0
0.83815	0.50503	0.96335	1.013	15.00	10.00	150.0
0.77634	0.41878	0.94357	1.262	15.00	10.00	150.0
0.69939	0.33497	0.91487	1.512	15.00	10.00	150.0
0.60928	0.25829	0.87473	1.762	15.00	10.00	150.0
0.51106	0.19223	0.82114	2.012	15.00	10.00	150.0
0.41197	0.13842	0.75340	2.262	15.00	10.00	150.0
0.31954	0.09676	0.67304	2.512	15.00	10.00	150.0
0.23940	0.06591	0.58401	2.762	15.00	10.00	150.0
0.17422	0.04392	0.49209	3.012	15.00	10.00	150.0
0.12389	0.02873	0.40338	3.262	15.00	10.00	150.0
0.08658	0.01850	0.32282	3.512	15.00	10.00	150.0
0.05973	0.01176	0.25333	3.762	15.00	10.00	150.0
0.04084	0.00739	0.19582	4.012	15.00	10.00	150.0
0.02775	0.00461	0.14971	4.262	15.00	10.00	150.0
0.01877	0.00285	0.11359	4.512	15.00	10.00	150.0
0.01266	0.00175	0.08576	4.762	15.00	10.00	150.0
0.00852	0.00107	0.06456	5.012	15.00	10.00	150.0
0.00573	0.00065	0.04852	5.262	15.00	10.00	150.0
0.00383	0.00039	0.03645	5.512	15.00	10.00	150.0
0.00258	0.00024	0.02738	5.762	15.00	10.00	150.0
0.00173	0.00014	0.02058	6.012	15.00	10.00	150.0
0.00116	0.00009	0.01548	6.262	15.00	10.00	150.0
0.00078	0.00005	0.01166	6.512	15.00	10.00	150.0
0.00052	0.00003	0.00878	6.762	15.00	10.00	150.0
0.00035	0.00002	0.00663	7.012	15.00	10.00	150.0

AREA UNDER FITTED PROBABILITY FOR VARIABLE 1

UPPER	FITTED	LOWER
3.0454	2.0393	1.1180

APPENDIX B

RAW DATA

(SEPTEMBER 1978 VISUAL SEARCH EXPERIMENT)

B.0 INTRODUCTION

This appendix contains raw data files for individual units on a daily basis. These files were used to form the aggregate files used in the LOGODDs computer runs.

The following is a key to the format of the raw data files:

Column 1: Detection (1 = Yes, 0 = No)
Column 2: Lateral Range (Nautical Miles)
Column 3: Duration of Search (Hours)
Column 4: Meteorological Visibility (Nautical Miles)
Column 5: Wind Velocity (Knots)
Column 6: Cloud Cover (1/10ths)
Column 7: Swell Height (Feet)
Column 8: Unit Speed (Knots)
Column 9: Elevation of Sun (Degrees)
Column 10: Altitude (Feet; Aircraft only)

41385. - 13 SEPT 78

1	0.50	1.10	20.00	15.00	0.20	3.00	10.50	49.00
1	0.20	1.50	20.00	15.00	0.20	3.00	10.50	53.00
0	1.00	3.20	20.00	12.00	0.20	3.00	10.50	52.00
0	0.60	5.50	20.00	8.00	0.10	2.00	10.50	34.00
0	0.80	5.70	20.00	8.00	0.10	2.00	10.50	32.00

PT. KNOLL - 13 SEPT 78

0	0.97	0.10	20.00	18.00	0.30	3.00	15.00	44.00
1	0.25	1.80	20.00	15.00	0.20	3.00	15.00	53.00
1	1.00	2.20	20.00	15.00	0.20	3.00	15.00	53.00
1	1.10	3.10	20.00	12.00	0.20	3.00	8.00	50.00
1	1.30	3.60	20.00	20.00	0.10	2.00	8.00	47.00
0	1.40	4.00	20.00	10.00	0.10	2.00	8.00	43.00
0	1.70	4.60	20.00	8.00	0.10	2.00	8.00	39.00
1	0.00	5.70	20.00	8.00	0.10	2.00	8.00	27.00
0	5.00	2.20	20.00	15.00	0.20	3.00	15.00	53.00
0	5.20	0.10	20.00	18.00	0.30	3.00	15.00	44.00

PT. TURNER - 13 SEPT 78

0	2.20	0.50	20.00	18.00	0.30	3.00	15.00	43.00
0	1.40	1.30	20.00	15.00	0.30	3.00	15.00	48.00
0	0.30	1.60	20.00	15.00	0.30	3.00	15.00	50.00
0	1.30	2.20	20.00	12.00	0.20	3.00	15.00	52.00
1	0.30	2.70	20.00	12.00	0.20	3.00	15.00	50.00
1	0.25	4.70	20.00	12.00	0.20	2.00	17.00	43.00
1	1.60	5.00	20.00	8.00	0.10	2.00	17.00	41.00
1	0.75	6.00	20.00	8.00	0.10	2.00	17.00	31.00
1	2.80	1.30	20.00	12.00	0.20	3.00	15.00	52.00
0	2.30	2.80	20.00	15.00	0.20	3.00	15.00	53.00
0	2.60	5.60	20.00	8.00	0.10	2.00	17.00	35.00
0	3.05	0.80	20.00	18.00	0.30	3.00	15.00	45.00
0	4.00	5.40	20.00	8.00	0.10	2.00	17.00	37.00

HH3 14 SEPT

0	3. 50	0. 13	25. 00	15. 00	0. 20	2. 00	80. 00	42. 00	500. 00
1	3. 80	0. 45	25. 00	15. 00	0. 20	2. 00	80. 00	44. 00	500. 00
1	1. 00	0. 72	25. 00	15. 00	0. 20	2. 00	80. 00	46. 00	500. 00
0	2. 10	1. 73	25. 00	15. 00	0. 20	2. 00	80. 00	51. 00	1000. 00
1	1. 50	1. 75	25. 00	15. 00	0. 20	2. 00	80. 00	51. 00	1000. 00
0	2. 80	1. 85	25. 00	15. 00	0. 20	2. 00	80. 00	52. 00	1000. 00
0	2. 60	2. 03	25. 00	15. 00	0. 20	2. 00	80. 00	52. 00	1000. 00
0	4. 30	1. 95	25. 00	15. 00	0. 20	2. 00	80. 00	52. 00	1000. 00
0	2. 20	0. 03	25. 00	15. 00	0. 20	2. 00	80. 00	48. 00	500. 00
1	2. 00	0. 08	25. 00	15. 00	0. 20	2. 00	80. 00	48. 00	500. 00
0	5. 00	0. 20	25. 00	15. 00	0. 20	2. 00	80. 00	47. 00	500. 00
1	4. 80	0. 30	25. 00	15. 00	0. 20	2. 00	80. 00	46. 00	500. 00
0	5. 60	0. 37	25. 00	15. 00	0. 20	2. 00	80. 00	46. 00	500. 00
1	2. 40	0. 45	25. 00	15. 00	0. 20	2. 00	80. 00	45. 00	1000. 00
1	0. 90	0. 60	25. 00	15. 00	0. 20	2. 00	80. 00	44. 00	1000. 00
0	5. 00	0. 68	25. 00	15. 00	0. 20	2. 00	80. 00	44. 00	1000. 00

HH52A 14 SEPT 78

0	4. 20	0. 17	25. 00	15. 00	0. 20	3. 00	85. 00	51. 00	500. 00
0	6. 50	0. 30	25. 00	15. 00	0. 20	3. 00	85. 00	52. 00	500. 00
0	3. 80	0. 42	25. 00	15. 00	0. 20	3. 00	85. 00	52. 00	500. 00
1	0. 75	0. 50	25. 00	15. 00	0. 20	3. 00	85. 00	52. 00	500. 00
0	0. 80	0. 67	25. 00	15. 00	0. 20	3. 00	85. 00	52. 00	500. 00
0	6. 70	1. 50	25. 00	15. 00	0. 20	3. 00	55. 00	50. 00	1000. 00
1	0. 75	1. 87	25. 00	15. 00	0. 20	3. 00	55. 00	49. 00	1000. 00
0	2. 00	1. 93	25. 00	15. 00	0. 20	3. 00	55. 00	49. 00	1000. 00
1	0. 50	1. 98	25. 00	15. 00	0. 20	3. 00	55. 00	48. 00	1000. 00
0	4. 20	2. 05	25. 00	15. 00	0. 20	3. 00	55. 00	48. 00	1000. 00

41441 18 SEPT 78

1	0.80	0.00	4.50	10.00	1.00	1.50	15.00	47.00
0	1.80	0.15	4.50	10.00	1.00	1.50	15.00	48.00
0	1.20	0.25	4.50	10.00	1.00	1.50	15.00	48.00
1	0.50	3.80	6.00	10.00	1.00	2.50	8.00	37.00
1	0.50	4.15	6.00	10.00	1.00	2.50	8.00	33.00
1	0.00	4.33	6.00	10.00	1.00	2.50	8.00	32.00
0	1.10	4.23	6.00	10.00	1.00	2.50	8.00	33.00
0	2.20	4.00	6.00	10.00	1.00	2.50	8.00	41.00

44348 18 SEPT 78

1	0.85	0.65	5.00	12.50	1.00	2.00	10.00	35.00
0	3.90	0.45	5.00	12.50	1.00	2.00	10.00	34.00

PT. JACKSON - 18 SEPT 78

1	3.00	0.13	5.00	7.00	1.00	1.50	15.00	48.00
0	5.80	0.47	5.00	7.00	1.00	1.50	15.00	50.00
0	7.20	0.40	5.00	7.00	1.00	1.50	15.00	49.00
1	0.85	1.00	5.00	7.00	1.00	1.50	15.00	50.00
0	1.70	1.07	3.00	7.00	1.00	1.50	15.00	50.00
1	1.50	1.05	3.00	7.00	1.00	1.50	15.00	50.00
0	0.75	2.65	10.00	9.00	1.00	2.00	8.00	45.00
1	0.75	2.83	10.00	9.00	1.00	2.00	8.00	44.00
0	1.00	2.93	10.00	9.00	1.00	2.00	8.00	43.00
0	4.50	3.31	10.00	9.00	1.00	2.00	8.00	40.00
0	1.25	3.40	10.00	9.00	1.00	2.00	8.00	40.00
0	2.25	3.70	10.00	9.00	1.00	2.00	8.00	37.00

PT. WELLS - 18 SEPT 78

1	0. 20	0. 30	2. 00	12. 00	1. 00	1. 00	1. 00	50. 00
0	3. 60	0. 43	2. 00	12. 00	1. 00	1. 00	1. 00	50. 00
0	2. 80	0. 56	2. 00	12. 00	1. 00	1. 00	1. 00	50. 00
0	1. 40	0. 93	2. 00	12. 00	1. 00	1. 00	1. 00	50. 00
1	1. 00	1. 01	2. 00	12. 00	1. 00	1. 00	1. 00	50. 00
1	0. 25	1. 13	8. 00	12. 00	1. 00	1. 00	1. 00	49. 00
1	2. 20	1. 15	8. 00	12. 00	1. 00	1. 00	1. 00	49. 00
0	2. 50	2. 41	10. 00	12. 00	1. 00	2. 00	1. 00	43. 00
1	0. 20	2. 53	10. 00	12. 00	1. 00	2. 00	1. 00	42. 00
0	2. 50	2. 70	10. 00	12. 00	1. 00	2. 00	1. 00	40. 00
1	0. 00	2. 80	10. 00	12. 00	1. 00	2. 00	1. 00	40. 00
0	2. 85	3. 13	5. 00	12. 00	1. 00	2. 00	1. 00	37. 00
0	1. 40	3. 48	5. 00	12. 00	1. 00	2. 00	1. 00	34. 00
0	3. 10	3. 51	5. 00	12. 00	1. 00	2. 00	1. 00	34. 00

HC130 20 SEPT 78

0	3.60	0.10	15.00	3.00	0.00	2.00	150.00	38.00	1000.00
0	3.60	0.13	15.00	3.00	0.00	2.00	150.00	38.00	1000.00
1	0.40	0.15	15.00	3.00	0.00	2.00	150.00	38.00	1000.00
1	1.10	0.20	15.00	3.00	0.00	2.00	150.00	39.00	1000.00
0	3.60	0.23	15.00	3.00	0.00	2.00	150.00	39.00	1000.00
0	4.10	0.25	15.00	3.00	0.00	2.00	150.00	39.00	1000.00
0	1.10	0.12	15.00	2.00	0.00	1.50	200.00	42.00	1000.00
0	2.70	0.13	15.00	2.00	0.00	1.50	200.00	42.00	1000.00
0	2.70	0.15	15.00	2.00	0.00	1.50	200.00	42.00	1000.00
1	0.30	0.17	15.00	2.00	0.00	1.50	200.00	42.00	1000.00
1	1.20	0.25	15.00	2.00	0.00	1.50	200.00	43.00	1000.00
0	0.90	0.02	15.00	5.00	0.00	1.00	150.00	44.00	1000.00
0	3.00	0.03	15.00	5.00	0.00	1.00	150.00	44.00	1000.00
1	3.00	0.07	15.00	5.00	0.00	1.00	150.00	44.00	1000.00
0	2.65	0.07	15.00	5.00	0.00	1.00	150.00	44.00	1000.00
0	1.50	0.10	15.00	5.00	0.00	1.00	150.00	44.00	1000.00
0	5.20	0.10	15.00	5.00	0.00	1.00	150.00	45.00	1000.00
1	2.20	0.18	15.00	5.00	0.00	1.00	150.00	43.00	1000.00
0	1.30	0.22	15.00	5.00	0.00	1.00	150.00	43.00	1000.00
1	1.40	0.50	15.00	5.00	0.00	1.00	200.00	41.00	1000.00
1	0.90	0.55	15.00	5.00	0.00	1.00	200.00	41.00	1000.00
0	2.20	0.53	15.00	5.00	0.00	1.00	200.00	41.00	1000.00
0	3.00	0.60	15.00	5.00	0.00	1.00	200.00	40.00	1000.00
0	5.50	0.57	15.00	5.00	0.00	1.00	200.00	40.00	1000.00

HH-3	20 SEPT 78								
1	1.25	0.10	15.00	2.00	0.00	2.00	90.00	41.00	500.00
0	4.40	0.00	15.00	2.00	0.00	2.00	90.00	40.00	500.00
1	2.70	0.20	15.00	2.00	0.00	2.00	90.00	42.00	500.00
1	0.60	0.20	15.00	2.00	0.00	2.00	90.00	42.00	500.00
0	5.20	0.20	15.00	2.00	0.00	2.00	90.00	43.00	500.00
1	1.00	0.30	15.00	2.00	0.00	2.00	90.00	43.00	500.00
0	4.30	0.40	15.00	2.00	0.00	2.00	90.00	44.00	500.00
1	2.10	0.50	15.00	2.00	0.00	2.00	90.00	44.00	500.00
1	0.80	0.90	15.00	5.00	0.00	2.00	90.00	45.00	500.00
0	5.20	1.00	15.00	5.00	0.00	1.50	60.00	47.00	500.00
1	2.60	1.00	15.00	5.00	0.00	1.50	60.00	47.00	500.00
1	0.10	1.10	15.00	5.00	0.00	1.50	60.00	47.00	500.00
1	0.75	0.10	15.00	5.00	0.00	1.50	90.00	45.00	500.00
0	3.90	0.30	15.00	5.00	0.00	1.50	90.00	44.00	500.00
1	0.80	0.30	15.00	5.00	0.00	1.50	90.00	44.00	500.00
0	1.60	0.80	15.00	5.00	0.00	1.50	90.00	40.00	500.00
1	2.00	0.60	15.00	5.00	0.00	1.50	90.00	42.00	500.00
0	1.70	0.65	15.00	5.00	0.00	1.50	90.00	42.00	500.00
0	1.40	0.80	15.00	7.00	0.00	1.50	60.00	40.00	500.00
1	1.00	0.80	15.00	7.00	0.00	1.50	60.00	40.00	500.00
1	1.60	0.90	15.00	7.00	0.00	1.50	60.00	39.00	500.00
0	3.75	0.90	15.00	7.00	0.00	1.50	60.00	39.00	500.00
0	1.80	1.00	10.00	7.00	0.00	1.50	60.00	38.00	500.00
0	1.50	0.80	15.00	5.00	0.00	1.50	60.00	39.00	500.00
1	1.50	0.90	15.00	7.00	0.00	1.50	60.00	39.00	500.00

HH 52A - 20 SEPT 78

1	1. 70	0. 22	15. 00	5. 00	0. 00	1. 50	85. 00	50. 00	750. 00
1	0. 20	0. 32	15. 00	5. 00	0. 00	1. 50	85. 00	50. 00	750. 00
0	4. 50	0. 45	15. 00	5. 00	0. 00	1. 50	85. 00	50. 00	750. 00
0	1. 50	0. 45	15. 00	5. 00	0. 00	1. 50	85. 00	50. 00	750. 00
1	2. 25	0. 53	15. 00	5. 00	0. 00	1. 50	85. 00	49. 00	750. 00
1	1. 60	0. 80	15. 00	5. 00	0. 00	1. 50	60. 00	49. 00	750. 00
0	2. 00	0. 98	15. 00	5. 00	0. 00	1. 50	85. 00	48. 00	750. 00
1	0. 80	1. 21	15. 00	5. 00	0. 00	1. 50	85. 00	47. 00	750. 00
1	2. 60	1. 05	15. 00	5. 00	0. 00	1. 50	85. 00	48. 00	750. 00
1	0. 50	0. 23	10. 00	7. 00	0. 00	1. 50	85. 00	34. 00	750. 00
0	0. 00	0. 30	10. 00	10. 00	0. 00	1. 50	85. 00	33. 00	750. 00
0	2. 30	0. 37	10. 00	10. 00	0. 00	1. 50	85. 00	32. 00	750. 00
0	4. 00	0. 44	10. 06	10. 00	0. 00	1. 50	85. 00	31. 00	750. 00
0	1. 70	0. 44	10. 00	10. 00	0. 00	1. 50	85. 00	31. 00	750. 00
0	3. 20	0. 47	10. 00	10. 00	0. 00	1. 50	85. 00	31. 00	750. 00
0	1. 90	0. 50	10. 00	10. 00	0. 00	1. 50	85. 00	31. 00	750. 00
0	5. 20	1. 05	10. 00	10. 00	0. 00	1. 50	85. 00	48. 00	750. 00

HU - 16 20 SEPT 78

1	0. 10	0. 21	15. 00	5. 00	0. 00	1. 50	150. 00	50. 00	1250. 00
0	3. 50	0. 17	15. 00	5. 00	0. 00	1. 50	150. 00	50. 00	1250. 00
0	2. 75	0. 27	15. 00	5. 00	0. 00	1. 50	150. 00	50. 00	1250. 00
1	0. 55	0. 32	15. 00	5. 00	0. 00	1. 50	150. 00	50. 00	1250. 00
0	3. 40	0. 40	15. 00	5. 00	0. 00	1. 50	150. 00	50. 00	1250. 00
1	1. 58	0. 22	10. 00	7. 00	0. 00	1. 00	120. 00	37. 00	1250. 00
1	1. 45	0. 08	10. 00	7. 00	0. 00	1. 00	120. 00	39. 00	1250. 00
1	0. 60	0. 13	10. 00	7. 00	0. 00	1. 00	120. 00	38. 00	1250. 00
0	3. 20	0. 18	10. 00	7. 00	0. 00	1. 00	120. 00	38. 00	1250. 00
1	3. 30	0. 57	15. 00	3. 00	0. 00	1. 00	120. 00	50. 00	1250. 00
1	1. 60	0. 63	15. 00	3. 00	0. 00	1. 00	120. 00	49. 00	1250. 00
1	1. 75	0. 70	15. 00	3. 00	0. 00	1. 00	120. 00	49. 00	1250. 00
0	4. 70	0. 71	15. 00	3. 00	0. 00	1. 00	120. 00	49. 00	1250. 00
1	1. 10	0. 65	15. 00	3. 00	0. 00	1. 00	120. 00	49. 00	1250. 00
1	1. 75	0. 47	10. 00	10. 00	0. 00	1. 00	120. 00	35. 00	1250. 00
0	2. 75	0. 55	10. 00	10. 00	0. 00	1. 00	120. 00	34. 00	1250. 00
1	0. 65	0. 58	10. 00	10. 00	0. 00	1. 00	120. 00	34. 00	1250. 00

HC-130		21 SEPT 78							
0	2.60	0.10	8.00	10.00	0.00	1.50	150.00	45.00	1000.00
0	1.00	0.13	8.00	10.00	0.00	1.50	150.00	45.00	1000.00
0	0.90	0.15	8.00	10.00	0.00	1.50	150.00	45.00	1000.00
0	1.10	0.16	8.00	10.00	0.00	1.50	150.00	45.00	1000.00
0	2.80	0.17	8.00	10.00	0.00	1.50	150.00	46.00	1000.00
1	1.00	0.20	8.00	10.00	0.00	1.50	150.00	46.00	1000.00
1	0.80	0.25	8.00	10.00	0.00	1.50	150.00	46.00	1000.00
0	1.10	0.28	8.00	10.00	0.00	1.50	150.00	46.00	1000.00
0	4.00	0.31	8.00	10.00	0.00	1.50	150.00	46.00	1000.00
1	0.80	0.35	8.00	10.00	0.00	1.50	150.00	46.00	1000.00
0	3.40	3.20	8.00	12.00	0.00	3.00	150.00	42.00	1000.00
1	0.35	3.25	8.00	12.00	0.00	3.00	150.00	41.00	1000.00
0	3.30	3.28	8.00	12.00	0.00	3.00	150.00	41.00	1000.00
0	1.40	3.30	8.00	12.00	0.00	3.00	150.00	41.00	1000.00
0	0.50	3.38	8.00	12.00	0.00	3.00	150.00	40.00	1000.00
0	1.40	3.40	8.00	12.00	0.00	3.00	150.00	40.00	1000.00
0	4.70	3.33	8.00	12.00	0.00	3.00	150.00	41.00	1000.00
0	2.90	3.42	8.00	12.00	0.00	3.00	150.00	40.00	1000.00
1	0.50	3.45	8.00	12.00	0.00	3.00	150.00	40.00	1000.00
0	2.20	3.48	8.00	12.00	0.00	3.00	150.00	40.00	1000.00
0	2.00	0.08	8.00	10.00	0.00	1.50	150.00	42.00	1000.00
0	0.10	0.12	8.00	10.00	0.00	1.50	150.00	43.00	1000.00
1	1.20	0.15	8.00	10.00	0.00	1.50	150.00	43.00	1000.00
0	2.20	0.33	8.00	10.00	0.00	1.50	150.00	43.00	1000.00
0	0.50	0.22	8.00	10.00	0.00	1.50	150.00	43.00	1000.00
1	0.20	0.23	8.00	10.00	0.00	1.50	150.00	43.00	1000.00
0	2.10	0.16	8.00	10.00	0.00	1.50	150.00	43.00	1000.00
0	1.80	0.10	8.00	12.00	0.00	3.00	150.00	45.00	1000.00
0	0.00	0.14	8.00	12.00	0.00	3.00	150.00	45.00	1000.00
0	3.35	0.16	8.00	12.00	0.00	3.00	150.00	44.00	1000.00
0	2.30	0.17	8.00	12.00	0.00	3.00	150.00	44.00	1000.00
1	1.10	0.18	8.00	12.00	0.00	3.00	150.00	44.00	1000.00
0	0.75	0.23	8.00	12.00	0.00	3.00	150.00	43.00	1000.00
0	2.65	0.26	8.00	12.00	0.00	3.00	150.00	43.00	1000.00
0	2.40	0.22	8.00	12.00	0.00	3.00	150.00	43.00	1000.00
1	0.30	0.30	8.00	12.00	0.00	3.00	150.00	43.00	1000.00

HH52A 21 SEPT 78

0	2.75	0.88	8.00	10.00	0.00	2.00	60.00	49.00	500.00
0	2.10	1.13	8.00	10.00	0.00	2.00	60.00	48.00	500.00
0	0.30	1.23	8.00	10.00	0.00	2.00	60.00	48.00	500.00
0	2.00	1.35	8.00	10.00	0.00	2.00	60.00	48.00	500.00
0	2.10	1.38	8.00	10.00	0.00	2.00	60.00	48.00	500.00
1	0.80	1.38	8.00	10.00	0.00	2.00	60.00	48.00	500.00
0	3.00	1.60	8.00	10.00	0.00	2.00	60.00	47.00	500.00
1	0.50	1.68	8.00	10.00	0.00	2.00	60.00	46.00	500.00
0	3.80	0.23	8.00	10.00	0.00	1.50	85.00	49.00	500.00
1	1.80	0.22	8.00	10.00	0.00	1.50	85.00	49.00	500.00
0	2.00	0.28	8.00	10.00	0.00	1.50	85.00	49.00	500.00
1	0.10	0.33	8.00	10.00	0.00	1.50	85.00	49.00	500.00
0	2.50	0.47	8.00	10.00	0.00	1.50	85.00	49.00	500.00

HH-3 - 21 SEPT 78

1	0.40	0.37	8.00	12.00	0.00	3.00	80.00	39.00	500.00
0	0.40	0.48	8.00	12.00	0.00	3.00	80.00	38.00	500.00
0	1.50	0.65	8.00	12.00	0.00	3.00	80.00	37.00	500.00
1	0.20	0.72	8.00	12.00	0.00	3.00	80.00	36.00	500.00
0	3.75	0.75	8.00	12.00	0.00	3.00	80.00	36.00	500.00
0	1.10	0.83	8.00	12.00	0.00	3.00	80.00	35.00	500.00
0	3.70	0.86	8.00	12.00	0.00	3.00	80.00	35.00	500.00
0	0.40	0.27	8.00	10.00	0.00	1.50	120.00	42.00	500.00
0	6.00	0.32	8.00	10.00	0.00	1.50	120.00	43.00	500.00
1	3.00	0.35	8.00	10.00	0.00	1.50	120.00	43.00	500.00
1	0.75	0.38	8.00	10.00	0.00	1.50	120.00	43.00	500.00
1	1.40	0.60	8.00	10.00	0.00	1.50	120.00	44.00	500.00

PT TURNER - 22 SEPT 78

0	1.10	1.78	10.00	22.00	1.00	4.50	13.00	48.00
1	0.50	2.01	10.00	22.00	1.00	4.50	13.00	47.00
0	0.60	2.18	10.00	22.00	1.00	4.50	13.00	47.00
1	0.40	2.66	10.00	22.00	1.00	4.50	13.00	44.00
0	1.20	2.73	10.00	22.00	1.00	4.50	13.00	44.00
0	3.20	3.11	10.00	22.00	1.00	4.50	13.00	42.00
0	0.50	3.13	10.00	22.00	1.00	4.50	13.00	42.00
0	0.50	3.43	10.00	22.00	1.00	4.50	13.00	39.00
0	1.60	3.61	10.00	22.00	1.00	4.50	13.00	38.00
0	0.20	3.81	10.00	22.00	1.00	4.50	13.00	36.00
0	0.10	3.81	10.00	22.00	1.00	4.50	13.00	36.00
0	1.30	3.96	10.00	22.00	1.00	4.50	13.00	34.00
0	1.10	4.04	10.00	22.00	1.00	4.50	13.00	33.00
0	0.30	4.21	10.00	22.00	1.00	4.50	13.00	32.00
0	2.90	4.28	10.00	22.00	1.00	4.50	13.00	31.00
0	3.10	4.55	10.00	22.00	1.00	4.50	13.00	30.00
0	1.90	4.68	10.00	22.00	1.00	4.50	13.00	28.00
0	1.50	1.95	10.00	22.00	1.00	4.50	13.00	47.00
0	1.50	3.70	10.00	22.00	1.00	4.50	13.00	37.00

PT WELLS 22 SEPT 78

0	1.40	0.05	10.00	25.00	1.00	4.00	12.00	49.00
0	0.65	0.27	10.00	25.00	1.00	4.00	12.00	48.00
0	1.30	0.40	10.00	25.00	1.00	4.00	12.00	47.00
0	1.50	0.65	10.00	25.00	1.00	4.00	12.00	47.00
0	0.50	0.88	10.00	25.00	1.00	4.00	12.00	46.00
0	0.90	0.90	10.00	25.00	1.00	4.00	12.00	46.00
0	0.40	1.02	10.00	25.00	1.00	4.00	12.00	45.00
0	1.00	1.14	10.00	25.00	1.00	5.00	12.00	44.00
0	0.30	1.26	10.00	22.00	1.00	5.00	12.00	44.00
0	2.80	1.48	10.00	25.00	1.00	5.00	12.00	42.00
0	1.70	1.93	10.00	25.00	1.00	5.00	12.00	39.00
0	1.00	2.43	10.00	25.00	1.00	5.00	12.00	36.00
1	0.65	2.63	10.00	25.00	1.00	5.00	12.00	33.00
1	0.30	2.96	10.00	21.00	1.00	4.00	12.00	30.00
1	0.50	3.09	10.00	21.00	1.00	4.00	12.00	29.00
0	0.70	3.22	10.00	21.00	1.00	4.00	12.00	28.00
0	2.10	2.65	10.00	21.00	1.00	4.00	12.00	33.00
0	2.20	2.55	10.00	21.00	1.00	4.00	12.00	34.00

41342 - 25 SEPT 78

1	0.28	0.07	10.00	13.00	0.00	1.50	10.00	45.00
1	2.25	0.10	10.00	13.00	0.00	1.50	10.00	46.00
1	1.10	0.13	10.00	13.00	0.00	1.50	10.00	45.00
0	2.20	0.71	10.00	13.00	0.00	1.50	10.00	47.00
0	1.50	1.08	10.00	13.00	0.00	1.50	10.00	47.00
0	1.70	1.36	10.00	13.00	0.00	1.50	10.00	47.00
1	0.10	1.38	10.00	13.00	0.00	1.50	10.00	47.00
0	2.70	1.63	10.00	13.00	0.00	1.50	10.00	45.00
0	1.20	1.83	10.00	13.00	0.00	1.50	10.00	44.00
0	1.50	1.96	10.00	13.00	0.00	1.50	10.00	43.00
1	0.80	2.17	10.00	13.00	0.00	1.50	10.00	42.00
1	4.40	2.30	10.00	13.00	0.00	1.50	10.00	42.00
1	2.45	2.30	10.00	13.00	0.00	1.50	10.00	42.00
0	6.75	2.22	10.00	13.00	0.00	1.50	10.00	42.00
0	4.10	3.22	10.00	13.00	0.00	1.50	20.00	35.00
1	2.45	2.57	10.00	13.00	0.00	1.50	20.00	40.00
0	4.50	2.63	10.00	13.00	0.00	1.50	20.00	40.00
1	1.00	2.62	10.00	13.00	0.00	1.50	20.00	40.00
0	3.30	2.88	10.00	13.00	0.00	1.50	20.00	38.00
1	0.26	2.85	10.00	13.00	0.00	1.50	20.00	38.00
0	3.00	3.02	10.00	13.00	0.00	1.50	20.00	37.00
1	1.45	2.80	10.00	13.00	0.00	1.50	20.00	38.00
0	3.00	3.02	10.00	13.00	0.00	1.50	20.00	37.00
1	0.55	3.03	12.00	11.00	0.00	1.50	20.00	37.00
1	0.95	3.37	15.00	10.00	0.00	1.50	20.00	33.00
0	2.60	3.29	15.00	10.00	0.00	1.50	20.00	34.00
0	3.20	3.42	15.00	10.00	0.00	1.50	20.00	33.00
0	5.40	3.39	15.00	10.00	0.00	1.50	20.00	33.00

41385 - 25 SEPT 78

1	0.00	0.00	10.00	10.00	0.00	1.50	15.00	39.00
1	1.50	0.13	10.00	10.00	0.00	1.50	15.00	40.00
0	1.10	0.36	10.00	10.00	0.00	1.50	15.00	41.00
0	2.60	0.62	10.00	10.00	0.00	1.50	15.00	42.00
0	4.00	0.77	10.00	10.00	0.00	1.50	15.00	44.00
1	2.80	0.97	10.00	10.00	0.00	1.50	15.00	44.00
1	0.20	1.17	10.00	10.00	0.00	1.50	8.00	45.00
1	1.75	1.37	10.00	13.00	0.00	1.50	8.00	46.00
1	0.75	1.45	10.00	13.00	0.00	1.50	8.00	47.00
0	4.00	1.62	10.00	13.00	0.00	1.50	8.00	47.00
1	0.30	1.87	10.00	13.00	0.00	1.50	8.00	48.00
0	2.50	0.13	10.00	13.00	0.00	1.50	8.00	40.00
0	2.60	2.82	10.00	13.00	0.00	1.50	8.00	43.00
1	1.25	2.95	10.00	13.00	0.00	1.50	8.00	45.00
1	0.50	3.62	10.00	13.00	0.00	1.50	8.00	42.00
0	1.70	3.72	10.00	13.00	0.00	1.50	8.00	41.00
0	3.10	3.72	10.00	13.00	0.00	1.50	8.00	41.00
1	3.40	4.04	10.00	13.00	0.00	1.50	8.00	38.00
0	1.00	4.17	10.00	13.00	0.00	1.50	8.00	38.00
0	1.10	4.27	10.00	13.00	0.00	1.50	8.00	37.00
1	0.75	4.37	10.00	13.00	0.00	1.50	8.00	33.00
0	3.50	4.57	15.00	10.00	0.00	1.50	8.00	35.00
0	1.75	4.79	15.00	10.00	0.00	1.50	8.00	32.00
0	0.20	5.07	15.00	10.00	0.00	1.50	8.00	30.00
0	2.40	4.05	15.00	10.00	0.00	1.50	8.00	38.00

CAPE GEORGE - 25 SEPT 78

1	1.70	0.00	10.00	9.50	0.00	1.50	15.00	42.00
0	3.60	0.20	10.00	9.50	0.00	1.50	15.00	43.00
1	1.20	0.30	10.00	9.50	0.00	1.50	15.00	43.00
1	1.00	0.40	10.00	9.50	0.00	1.50	15.00	44.00
1	3.10	0.60	10.00	9.50	0.00	1.50	15.00	45.00
0	3.60	0.60	10.00	14.00	0.00	1.50	15.00	45.00
1	1.90	0.70	10.00	14.00	0.00	1.50	15.00	46.00
0	5.70	0.80	10.00	14.00	0.00	1.50	15.00	46.00
1	0.00	1.10	10.00	14.00	0.00	1.50	15.00	47.00
0	1.10	1.20	10.00	14.00	0.00	1.50	15.00	47.00
0	3.70	1.20	10.00	14.00	0.00	1.50	15.00	47.00
0	2.75	1.40	10.00	13.50	0.00	1.50	15.00	47.00
1	1.80	1.20	10.00	13.50	0.00	1.50	15.00	47.00
0	2.10	1.50	10.00	13.50	0.00	1.50	8.00	47.00
0	0.80	1.70	10.00	13.50	0.00	1.50	8.00	47.00
1	0.80	2.20	10.00	13.50	0.00	1.50	8.00	46.00
1	0.00	2.40	10.00	13.50	0.00	1.50	8.00	45.00
1	1.40	2.40	10.00	13.50	0.00	1.50	8.00	45.00
1	2.00	2.60	10.00	12.50	0.00	1.50	8.00	44.00
0	3.60	2.70	10.00	12.50	0.00	1.50	8.00	44.00
0	1.00	3.00	10.00	12.50	0.00	1.50	8.00	43.00
1	1.75	3.00	10.00	12.50	0.00	1.50	8.00	43.00
1	1.45	3.40	15.00	10.00	0.00	1.50	8.00	39.00
1	2.70	3.60	15.00	10.00	0.00	1.50	8.00	38.00
0	3.20	1.83	10.00	13.00	0.00	1.50	8.00	47.00
0	1.70	2.00	10.00	13.00	0.00	1.50	8.00	47.00
0	3.50	2.18	10.00	13.00	0.00	1.50	8.00	46.00
0	2.20	2.70	10.00	13.00	0.00	1.50	8.00	44.00

PT KNOLL - 25 SEPT 78

1	0.00	0.13	10.00	10.00	0.00	1.50	8.00	39.00
0	2.30	0.23	10.00	10.00	0.00	1.50	8.00	40.00
0	1.90	0.63	10.00	10.00	0.00	1.50	8.00	42.00
0	4.00	0.75	10.00	10.00	0.00	1.50	8.00	43.00
0	1.85	1.07	10.00	10.00	0.00	1.50	8.00	44.00
0	0.05	1.42	10.00	10.00	0.00	1.50	8.00	46.00
1	2.10	1.52	10.00	14.00	0.00	1.50	8.00	47.00
1	0.40	1.62	10.00	14.00	0.00	1.50	8.00	47.00
1	0.65	1.87	10.00	14.00	0.00	1.50	8.00	47.00
1	1.60	1.87	10.00	14.00	0.00	1.50	8.00	47.00
0	3.90	1.85	10.00	14.00	0.00	1.50	8.00	47.00
1	2.40	2.35	10.00	14.00	0.00	1.50	15.00	46.00
1	0.25	2.70	10.00	14.00	0.00	1.50	15.00	44.00
1	1.20	2.93	10.00	14.00	0.00	1.50	15.00	43.00
0	4.30	2.77	10.00	14.00	0.00	1.50	15.00	44.00
0	1.90	3.11	10.00	11.00	0.00	1.50	15.00	42.00
1	0.50	3.01	10.00	11.00	0.00	1.50	15.00	42.00
1	0.55	3.14	10.00	11.00	0.00	1.50	15.00	42.00
0	2.90	3.27	10.00	11.00	0.00	1.50	15.00	40.00
1	0.15	3.55	10.00	11.00	0.00	1.50	15.00	39.00
0	0.80	3.45	10.00	11.00	0.00	1.50	15.00	39.00
0	3.60	3.78	10.00	11.00	0.00	1.50	15.00	38.00
0	1.85	4.15	10.00	11.00	0.00	1.50	15.00	34.00
0	2.00	2.70	10.00	11.00	0.00	1.50	15.00	44.00
0	3.50	2.95	10.00	11.00	0.00	1.50	15.00	43.00

HH 52A - 26 SEPT 78

1	1. 50	0. 03	15. 00	3. 00	0. 00	1. 00	85. 00	45. 00	1000. 00
1	3. 90	0. 11	15. 00	3. 00	0. 00	1. 00	85. 00	45. 00	1000. 00
1	2. 00	0. 33	15. 00	3. 00	0. 00	1. 00	85. 00	44. 00	1000. 00
0	6. 25	0. 08	15. 00	3. 00	0. 00	1. 00	85. 00	45. 00	1000. 00
1	1. 75	0. 48	15. 00	3. 00	0. 00	1. 00	85. 00	44. 00	1000. 00
0	5. 00	0. 60	15. 00	3. 00	0. 00	1. 00	85. 00	43. 00	1000. 00
1	2. 75	0. 62	15. 00	3. 00	0. 00	1. 00	85. 00	43. 00	1000. 00
1	2. 00	0. 72	15. 00	3. 00	0. 00	1. 00	85. 00	43. 00	1000. 00
1	0. 75	0. 82	15. 00	3. 00	0. 00	1. 00	85. 00	42. 00	1000. 00
0	5. 75	0. 75	15. 00	3. 00	0. 00	1. 00	85. 00	43. 00	1000. 00
1	2. 80	0. 90	15. 00	3. 00	0. 00	1. 00	85. 00	42. 00	1000. 00
1	0. 70	1. 00	15. 00	3. 00	0. 00	1. 00	85. 00	41. 00	1000. 00
0	6. 60	1. 03	15. 00	3. 00	0. 00	1. 00	85. 00	41. 00	1000. 00
0	4. 30	0. 98	15. 00	3. 00	0. 00	1. 00	85. 00	41. 00	1000. 00
1	1. 10	0. 28	15. 00	3. 00	0. 00	1. 00	85. 00	45. 00	1000. 00
1	3. 20	0. 33	15. 00	3. 00	0. 00	1. 00	85. 00	44. 00	1000. 00
0	4. 70	0. 45	15. 00	3. 00	0. 00	1. 00	85. 00	44. 00	1000. 00

HU-16 26 SEPT 78

1	1. 85	0. 13	15. 00	3. 00	0. 00	1. 00	145. 00	41. 00	1000. 00
0	5. 80	0. 17	15. 00	3. 00	0. 00	1. 00	145. 00	41. 00	1000. 00
1	1. 80	0. 25	15. 00	3. 00	0. 00	1. 00	145. 00	42. 00	1000. 00
0	2. 80	0. 25	15. 00	3. 00	0. 00	1. 00	145. 00	42. 00	1000. 00
0	3. 90	0. 30	15. 00	3. 00	0. 00	1. 00	145. 00	42. 00	1000. 00
1	0. 75	0. 33	15. 00	3. 00	0. 00	1. 00	145. 00	42. 00	1000. 00
0	4. 20	0. 73	15. 00	3. 00	0. 00	1. 00	120. 00	44. 00	500. 00
1	1. 05	0. 78	15. 00	3. 00	0. 00	1. 00	120. 00	44. 00	500. 00
1	1. 60	0. 82	15. 00	3. 00	0. 00	1. 00	120. 00	45. 00	500. 00
1	2. 70	0. 88	15. 00	3. 00	0. 00	1. 00	120. 00	45. 00	500. 00
1	3. 20	0. 77	15. 00	3. 00	0. 00	1. 00	120. 00	44. 00	500. 00
0	4. 70	0. 70	15. 00	3. 00	0. 00	1. 00	120. 00	44. 00	500. 00
0	4. 00	0. 83	15. 00	3. 00	0. 00	1. 00	120. 00	45. 00	500. 00
1	0. 70	0. 83	15. 00	3. 00	0. 00	1. 00	120. 00	45. 00	500. 00
1	1. 65	0. 03	15. 00	1. 00	0. 00	1. 00	143. 00	45. 00	500. 00
0	5. 50	0. 08	15. 00	1. 00	0. 00	1. 00	143. 00	45. 00	500. 00
1	2. 55	0. 08	15. 00	1. 00	0. 00	1. 00	143. 00	45. 00	500. 00
1	1. 25	0. 10	15. 00	1. 00	0. 00	1. 00	143. 00	45. 00	500. 00
1	1. 00	0. 13	15. 00	1. 00	0. 00	1. 00	143. 00	44. 00	500. 00
0	1. 90	0. 15	15. 00	3. 00	0. 00	1. 00	143. 00	44. 00	500. 00
1	2. 10	0. 22	15. 00	1. 00	0. 00	1. 00	143. 00	43. 00	500. 00
0	5. 70	0. 26	15. 00	1. 00	0. 00	1. 00	143. 00	43. 00	500. 00
1	1. 60	0. 30	15. 00	1. 00	0. 00	1. 00	143. 00	43. 00	500. 00
1	4. 40	0. 33	15. 00	1. 00	0. 00	1. 00	143. 00	43. 00	500. 00
0	2. 65	0. 43	15. 00	1. 00	0. 00	1. 00	145. 00	43. 00	500. 00
1	3. 60	0. 53	15. 00	1. 00	0. 00	1. 00	145. 00	42. 00	500. 00
1	1. 10	0. 57	15. 00	1. 00	0. 00	1. 00	145. 00	42. 00	500. 00
1	3. 90	0. 50	15. 00	1. 00	0. 00	1. 00	145. 00	43. 00	500. 00
1	0. 10	0. 45	15. 00	1. 00	0. 00	1. 00	145. 00	43. 00	500. 00
0	6. 90	0. 52	15. 00	1. 00	0. 00	1. 00	145. 00	42. 00	500. 00
0	3. 60	0. 53	15. 00	1. 00	0. 00	1. 00	145. 00	42. 00	500. 00
0	5. 00	0. 63	15. 00	1. 00	0. 00	1. 00	145. 00	41. 00	500. 00
1	0. 10	0. 65	15. 00	1. 00	0. 00	1. 00	145. 00	41. 00	500. 00

41413 27 SEPT 78

1	1. 10	0. 12	15. 00	2. 00	0. 10	1. 00	20. 00	41. 00
0	4. 80	0. 15	15. 00	2. 00	0. 10	1. 00	20. 00	41. 00
1	1. 25	0. 30	15. 00	2. 00	0. 10	1. 00	20. 00	42. 00
0	2. 00	0. 30	15. 00	2. 00	0. 10	1. 00	20. 00	42. 00
0	3. 25	0. 42	15. 00	2. 00	0. 10	1. 00	20. 00	42. 00
1	0. 40	0. 47	15. 00	2. 00	0. 10	1. 00	20. 00	43. 00
0	3. 00	0. 54	15. 00	2. 00	0. 10	1. 00	20. 00	43. 00
1	1. 60	0. 57	15. 00	2. 00	0. 10	1. 00	20. 00	43. 00
1	2. 00	0. 75	15. 00	2. 00	0. 10	1. 00	20. 00	44. 00
C	4. 00	0. 90	15. 00	2. 00	0. 10	1. 00	20. 00	45. 00
0	0. 80	1. 10	15. 00	2. 00	0. 10	1. 00	20. 00	45. 00
0	4. 50	1. 10	15. 00	2. 00	0. 10	1. 00	20. 00	45. 00

41441 27 SEPT 78

0	3. 80	0. 02	15. 00	2. 00	0. 70	1. 00	10. 00	41. 00
1	1. 00	0. 12	15. 00	1. 00	0. 60	1. 00	10. 00	42. 00
0	2. 90	0. 30	15. 00	1. 00	0. 50	1. 00	10. 00	43. 00
1	0. 40	0. 62	15. 00	2. 00	0. 50	1. 00	10. 00	44. 00
0	3. 40	0. 72	15. 00	3. 00	0. 40	1. 00	10. 00	45. 00
1	2. 70	0. 65	15. 00	4. 00	0. 30	1. 00	10. 00	44. 00
0	2. 70	1. 42	15. 00	7. 50	0. 20	1. 00	10. 00	47. 00
1	1. 25	1. 53	15. 00	7. 50	0. 20	1. 00	10. 00	47. 00
0	1. 60	1. 93	15. 00	7. 50	0. 30	1. 00	10. 00	47. 00
1	1. 30	2. 07	15. 00	7. 00	0. 40	1. 00	10. 00	46. 00
1	1. 00	3. 02	15. 00	7. 00	0. 50	1. 00	20. 00	42. 00
0	2. 90	3. 12	15. 00	7. 00	0. 60	1. 00	20. 00	42. 00
1	1. 60	3. 23	15. 00	7. 00	0. 80	1. 00	20. 00	41. 00
0	2. 40	3. 37	15. 00	6. 00	0. 90	1. 00	20. 00	40. 00
1	1. 60	3. 48	15. 00	6. 00	1. 00	1. 00	20. 00	39. 00
1	0. 25	1. 38	15. 00	7. 50	0. 02	1. 00	10. 00	38. 00
1	0. 25	3. 68	15. 00	6. 00	1. 00	1. 00	20. 00	47. 00
0	2. 00	2. 35	15. 00	7. 00	0. 50	1. 00	20. 00	45. 00
0	4. 10	2. 47	15. 00	7. 00	0. 50	1. 00	20. 00	44. 00

PT TURNER 27 SEPT 78

0	1.50	0.03	15.00	2.00	0.10	1.00	15.00	37.00
1	3.80	0.06	15.00	2.00	0.10	1.00	15.00	37.00
1	1.85	0.26	15.00	2.00	0.10	1.00	15.00	39.00
1	1.50	0.26	15.00	2.00	0.10	1.00	15.00	39.00
1	0.10	0.35	15.00	2.00	0.10	1.00	17.00	40.00
0	3.80	0.55	15.00	2.00	0.10	1.00	17.00	41.00
1	0.10	0.55	15.00	2.00	0.10	1.00	17.00	41.00
0	6.80	0.78	15.00	2.00	0.10	1.00	17.00	42.00
1	2.30	0.95	15.00	2.00	0.10	1.00	17.00	43.00
1	0.60	1.02	15.00	2.00	0.05	1.00	17.00	44.00
0	4.30	1.14	15.00	2.00	0.05	1.00	17.00	44.00
0	3.00	1.36	15.00	2.00	0.05	1.00	17.00	45.00
1	0.70	1.34	15.00	2.00	0.05	1.00	17.00	45.00
1	2.10	0.15	15.00	7.50	0.05	1.00	10.00	47.00
1	0.10	0.27	15.00	7.50	0.02	1.00	10.00	47.00
0	3.00	0.35	15.00	7.50	0.02	1.00	10.00	47.00
1	2.70	0.40	15.00	7.50	0.02	1.00	10.00	47.00
1	1.50	0.65	15.00	7.50	0.02	1.00	10.00	47.00
1	0.20	0.85	15.00	7.50	0.02	1.00	10.00	46.00
0	3.75	0.68	15.00	7.50	0.02	1.00	10.00	47.00
1	1.50	0.90	15.00	7.50	0.02	1.00	10.00	46.00
1	2.20	0.92	15.00	7.50	0.02	1.00	10.00	46.00
1	4.50	1.02	15.00	7.50	0.02	1.00	10.00	46.00
1	3.00	1.22	15.00	7.50	0.02	1.00	10.00	45.00
0	2.40	1.22	15.00	7.50	0.02	1.00	10.00	45.00
1	1.60	1.49	15.00	7.50	0.02	1.00	10.00	43.00
0	5.30	1.51	15.00	7.50	0.02	1.00	10.00	43.00
1	0.65	1.91	15.00	7.50	0.02	1.00	10.00	41.00
0	2.30	2.13	15.00	7.50	0.02	1.00	10.00	40.00

41413	**29**	**SEPT**	**78**					
C	5.90	0.17	15.00	3.00	0.00	1.50	20.00	41.00
1	0.20	0.17	15.00	2.00	0.00	1.50	20.00	41.00
0	4.85	0.63	15.00	2.00	0.00	1.50	20.00	43.00
1	1.20	0.57	15.00	2.00	0.00	1.50	20.00	43.00
1	1.65	0.70	15.00	2.00	0.00	1.50	20.00	43.00
1	0.10	0.92	15.00	1.00	0.00	1.00	20.00	45.00
0	2.50	0.98	15.00	1.00	0.00	1.00	20.00	45.00
0	5.90	0.87	15.00	1.00	0.00	1.00	20.00	44.00
0	4.10	1.20	15.00	2.00	0.05	1.00	20.00	45.00
1	0.90	2.08	15.00	3.00	0.10	1.50	20.00	46.00
1	3.60	2.46	15.00	3.00	0.07	1.50	10.00	45.00
0	2.30	2.70	15.00	3.00	0.06	1.50	10.00	45.00
0	0.80	2.98	15.00	3.00	0.05	1.00	10.00	43.00
1	0.20	3.45	15.00	4.00	0.05	1.50	10.00	41.00
0	2.25	3.53	15.00	4.00	0.05	1.50	10.00	40.00
0	4.70	3.37	15.00	6.00	0.05	1.50	10.00	41.00
0	6.20	4.55	15.00	6.00	0.05	1.50	10.00	32.00
0	3.40	4.92	15.00	7.50	0.05	1.50	10.00	29.00
1	1.00	5.02	15.00	7.50	0.05	1.50	10.00	27.00
0	4.20	2.00	15.00	3.00	0.10	1.50	10.00	47.00
0	4.00	3.10	15.00	4.00	0.05	1.50	10.00	42.00
44349	**29**	**SEPT**	**78**					
0	3.80	0.13	15.00	3.00	0.00	1.50	10.00	41.00
0	3.60	0.47	15.00	3.00	0.00	1.50	10.00	42.00
1	0.50	0.80	15.00	2.00	0.00	1.00	10.00	44.00
1	0.15	1.12	15.00	1.00	0.00	1.00	10.00	46.00
1	0.60	1.75	15.00	2.00	0.05	1.50	10.00	47.00
1	1.70	2.18	15.00	3.00	0.10	1.50	10.00	46.00
1	0.70	2.30	15.00	3.00	0.10	1.50	10.00	46.00
0	5.80	2.63	15.00	3.00	0.05	1.00	10.00	45.00
0	6.75	1.45	15.00	2.00	0.05	1.50	10.00	46.00
0	1.95	2.87	15.00	3.00	0.05	1.00	10.00	44.00
0	5.90	2.93	15.00	3.00	0.05	1.00	10.00	44.00
1	1.10	3.47	15.00	4.00	0.05	1.50	10.00	41.00
0	3.50	3.52	15.00	5.00	0.05	1.50	10.00	40.00

PT. TURNER SEPT 29 78

1	0.00	2.62	15.00	3.00	0.05	1.00	10.00	46.00
1	1.80	2.65	15.00	3.00	0.05	1.00	10.00	45.00
1	4.60	2.83	15.00	3.00	0.05	1.00	10.00	45.00
0	3.80	3.51	15.00	3.00	0.05	1.00	10.00	42.00
0	3.00	3.63	15.00	3.00	0.05	1.00	10.00	41.00
1	0.80	3.85	15.00	3.00	0.05	1.00	10.00	39.00
1	2.20	4.03	15.00	3.00	0.05	1.00	10.00	38.00
0	3.10	4.05	15.00	3.00	0.05	1.00	10.00	38.00
1	3.00	4.28	15.00	3.00	0.05	1.00	10.00	37.00
0	3.30	4.55	15.00	3.00	0.05	1.00	10.00	35.00
1	1.20	4.67	15.00	3.00	0.05	1.00	10.00	33.00
0	1.80	4.60	15.00	3.00	0.05	1.00	10.00	34.00
0	4.10	0.13	15.00	3.00	0.00	1.00	15.00	39.00
0	3.50	0.81	15.00	3.00	0.00	1.00	15.00	42.00
0	4.00	0.66	15.00	3.00	0.00	1.00	15.00	42.00
1	0.40	0.83	15.00	3.00	0.00	1.00	15.00	42.00
0	1.30	1.13	15.00	3.00	0.00	1.00	15.00	44.00
0	1.20	1.80	15.00	3.00	0.00	1.00	15.00	46.00
0	4.90	1.80	15.00	3.00	0.00	1.00	15.00	46.00
1	1.00	1.90	15.00	3.00	0.00	1.00	15.00	46.00
0	2.30	2.05	15.00	3.00	0.00	1.00	15.00	46.00
0	6.20	0.63	15.00	3.00	0.00	1.00	15.00	42.00
0	6.00	1.70	15.00	3.00	0.00	1.00	15.00	45.00
0	3.90	3.15	15.00	3.00	0.00	1.00	10.00	43.00
0	5.50	4.45	15.00	3.00	0.00	1.00	10.00	35.00
0	6.00	1.05	15.00	3.00	0.00	1.00	15.00	43.00
0	6.00	1.55	15.00	3.00	0.00	1.00	10.00	46.00

PT WELLS OCT 2 78

1	0.50	2.10	11.00	3.50	0.70	3.00	12.00	32.00
0	4.40	2.20	11.00	3.50	0.70	3.00	12.00	30.00
1	1.10	2.53	10.50	3.70	0.65	3.00	12.00	28.00
0	1.75	3.02	10.00	4.00	0.60	1.50	12.00	23.00
0	2.50	3.10	10.00	4.00	0.60	1.50	12.00	22.00
1	2.10	3.20	10.00	4.00	0.60	1.50	12.00	21.00
1	0.40	3.12	10.00	4.00	0.60	1.50	12.00	22.00
1	2.60	0.00	10.00	7.00	0.10	1.50	12.00	45.00
1	1.10	0.02	10.00	7.00	0.10	1.50	12.00	45.00
1	0.30	0.22	10.00	7.00	0.15	1.50	12.00	44.00
1	0.40	0.48	10.00	6.00	0.20	1.50	12.00	43.00
0	3.50	0.83	10.00	6.00	0.25	1.50	12.00	41.00
1	1.30	0.90	10.00	6.00	0.30	1.50	12.00	40.00
1	1.50	1.03	10.00	5.00	0.35	1.50	12.00	39.00
0	5.20	1.25	10.00	5.00	0.40	1.50	12.00	38.00
0	5.40	0.14	10.00	7.00	0.15	1.50	12.00	44.00

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1	1.70	0.00	12.00	11.50	0.10	2.00	20.00	38.00
1	0.05	0.28	12.00	11.50	0.10	2.00	20.00	39.00
C	4.00	0.27	12.00	11.50	0.10	2.00	20.00	39.00
0	1.60	0.65	12.00	11.00	0.10	2.00	20.00	41.00
1	0.40	0.82	12.00	10.00	0.10	2.00	20.00	42.00
0	3.50	0.70	12.00	10.00	0.10	2.00	20.00	42.00
0	2.10	1.02	12.00	10.00	0.10	2.00	20.00	43.00
1	0.30	1.45	12.00	9.00	0.10	2.00	10.00	44.00
1	0.10	1.90	12.00	9.00	0.10	2.00	10.00	45.00
0	4.00	1.88	12.00	8.00	0.10	2.00	10.00	45.00
1	0.55	2.58	10.00	7.00	0.10	2.00	10.00	44.00
1	1.70	2.90	10.00	7.00	0.15	2.00	10.00	43.00
0	3.30	3.03	10.00	6.00	0.20	2.00	10.00	43.00
0	3.30	2.63	10.00	7.00	0.10	2.00	10.00	44.00
0	2.10	0.39	12.00	11.50	0.10	2.00	20.00	40.00

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0	2.00	0.08	12.00	11.50	0.10	2.00	10.00	38.00
1	1.20	0.22	12.00	11.50	0.10	2.00	10.00	39.00
1	0.75	0.60	12.00	11.50	0.10	2.00	10.00	41.00
1	0.90	0.72	12.00	11.50	0.10	2.00	10.00	42.00
0	4.60	0.72	12.00	11.50	0.10	2.00	10.00	42.00
1	2.40	1.02	12.00	10.00	0.10	2.00	10.00	43.00
0	2.75	1.18	12.00	10.00	0.10	2.00	10.00	43.00
0	1.50	1.28	12.00	10.00	0.10	2.00	10.00	44.00
1	1.50	1.50	12.00	10.00	0.10	2.00	10.00	45.00
1	0.00	1.62	12.00	9.00	0.10	2.00	10.00	45.00
0	4.10	1.70	12.00	9.00	0.10	2.00	10.00	45.00
0	5.00	2.08	11.00	9.00	0.10	2.00	10.00	46.00
1	1.90	2.03	11.00	8.00	0.10	2.00	10.00	46.00
0	3.90	2.58	11.00	7.00	0.10	1.50	15.00	46.00
1	0.90	2.58	11.00	7.00	0.10	1.50	15.00	46.00
1	0.90	2.76	11.00	7.00	0.10	1.50	15.00	45.00
0	4.60	2.88	11.00	7.00	0.10	1.50	15.00	45.00
1	1.10	3.38	11.00	6.00	0.10	1.50	15.00	42.00
1	0.20	3.63	11.00	6.00	0.10	1.50	15.00	41.00
0	2.50	4.03	11.00	5.00	0.40	1.50	15.00	38.00
0	2.75	4.28	11.00	5.00	0.40	1.50	15.00	37.00
1	2.80	3.28	11.00	5.00	0.40	1.50	15.00	42.00
0	4.25	3.58	11.00	5.00	0.40	1.50	15.00	41.00

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1	1.40	0.40	10.00	7.00	0.10	1.50	10.00	44.00
1	1.50	0.72	10.00	6.00	0.10	1.50	10.00	43.00
0	3.60	0.73	10.00	6.00	0.10	1.50	10.00	43.00
1	0.50	1.05	10.00	6.00	0.20	1.50	10.00	41.00
1	0.75	1.45	10.00	5.00	0.40	1.50	10.00	38.00
0	3.50	1.50	10.00	5.00	0.40	1.50	10.00	37.00
0	3.25	2.33	11.00	3.50	0.70	2.00	10.00	31.00
1	1.60	3.27	10.00	4.00	0.60	1.50	10.00	22.00
0	2.20	3.37	10.00	4.00	0.60	1.50	10.00	21.00
0	1.25	0.20	10.00	7.00	0.10	1.50	10.00	44.00

HH52A		3 OCT	78						
0	5. 30	0. 12	15. 00	12. 00	0. 30	2. 00	60. 00	41. 00	500. 00
1	0. 00	0. 35	15. 00	12. 00	0. 30	2. 00	60. 00	42. 00	500. 00
1	2. 10	0. 37	15. 00	12. 00	0. 30	2. 00	60. 00	42. 00	500. 00
1	1. 80	0. 60	15. 00	12. 00	0. 30	2. 00	60. 00	43. 00	500. 00
0	5. 10	0. 67	15. 00	12. 00	0. 30	2. 00	60. 00	43. 00	500. 00
1	2. 20	0. 84	15. 00	12. 00	0. 30	2. 00	90. 00	44. 00	500. 00
0	3. 60	0. 94	15. 00	12. 00	0. 30	2. 00	90. 00	44. 00	500. 00
0	5. 50	1. 06	15. 00	12. 00	0. 30	2. 00	90. 00	45. 00	500. 00
1	2. 10	1. 14	15. 00	12. 00	0. 30	2. 00	90. 00	45. 00	500. 00
0	3. 25	0. 07	11. 00	9. 00	0. 50	2. 00	60. 00	44. 00	500. 00
1	2. 80	0. 07	11. 00	9. 00	0. 50	2. 00	60. 00	44. 00	500. 00
0	2. 90	0. 27	11. 00	9. 00	0. 60	2. 00	60. 00	44. 00	500. 00
0	1. 80	0. 34	11. 00	9. 00	0. 60	2. 00	60. 00	43. 00	500. 00
0	1. 50	0. 41	11. 00	11. 00	0. 70	2. 00	60. 00	43. 00	500. 00
1	1. 85	0. 58	11. 00	11. 00	0. 70	2. 00	60. 00	42. 00	500. 00
0	3. 00	0. 90	11. 00	13. 00	0. 80	2. 00	85. 00	40. 00	500. 00
0	1. 20	1. 02	11. 00	13. 00	0. 80	2. 00	85. 00	39. 00	500. 00
0	3. 10	1. 14	11. 00	13. 00	0. 80	2. 00	85. 00	38. 00	500. 00
1	1. 50	1. 16	11. 00	13. 00	0. 80	2. 00	85. 00	38. 00	500. 00
0	2. 75	1. 36	11. 00	13. 00	0. 80	2. 00	85. 00	37. 00	500. 00

41413	4	OCT	78					
1	0. 10	0. 23	10. 00	17. 00	0. 90	3. 00	10. 00	39. 00
0	1. 10	0. 37	10. 00	17. 00	0. 90	3. 00	10. 00	40. 00
1	0. 00	0. 55	10. 00	17. 00	0. 90	3. 00	10. 00	41. 00
1	0. 05	0. 60	10. 00	17. 00	0. 90	3. 00	10. 00	41. 00
0	2. 40	0. 65	10. 00	17. 00	0. 90	3. 00	10. 00	41. 00
0	1. 50	0. 72	10. 00	17. 00	0. 90	3. 00	10. 00	42. 00
0	1. 20	0. 94	10. 00	17. 00	0. 90	3. 00	10. 00	43. 00
0	1. 10	1. 09	10. 00	20. 00	0. 90	4. 00	10. 00	43. 00
0	0. 90	1. 32	10. 00	20. 00	0. 95	4. 00	10. 00	44. 00
44352		4	OCT	78				
0	0. 30	0. 02	11. 00	18. 00	0. 90	4. 00	10. 00	44. 00
0	0. 40	0. 09	11. 00	18. 00	0. 90	4. 00	10. 00	44. 00
0	0. 90	0. 19	11. 00	18. 00	0. 90	4. 00	10. 00	44. 00
0	0. 60	0. 56	12. 00	20. 00	0. 95	4. 00	10. 00	45. 00
0	0. 70	0. 94	12. 00	20. 00	0. 95	4. 00	10. 00	45. 00
0	3. 00	1. 10	12. 00	20. 00	0. 95	4. 00	10. 00	44. 00
PT TURNER		4	OCT	78				
0	1. 45	0. 20	10. 00	17. 00	0. 90	3. 00	15. 00	38. 00
0	1. 60	0. 38	10. 00	17. 00	0. 90	3. 00	15. 00	40. 00
1	0. 70	0. 40	10. 00	17. 00	0. 90	3. 00	15. 00	40. 00
1	0. 20	0. 52	10. 00	17. 00	0. 90	3. 00	15. 00	40. 00
0	2. 10	0. 62	10. 00	17. 00	0. 90	3. 00	15. 00	41. 00
0	2. 05	0. 65	10. 00	17. 00	0. 90	3. 00	15. 00	41. 00
1	0. 10	0. 92	10. 00	17. 00	0. 90	3. 00	15. 00	42. 00
1	0. 10	0. 97	10. 00	17. 00	0. 90	3. 00	15. 00	42. 00
0	1. 75	1. 02	11. 00	18. 00	0. 90	3. 00	15. 00	43. 00
0	2. 20	1. 02	11. 00	19. 00	0. 90	3. 00	15. 00	43. 00
0	1. 40	2. 17	12. 00	25. 00	0. 95	4. 00	10. 00	45. 00
0	0. 60	2. 33	12. 00	25. 00	0. 95	5. 00	10. 00	45. 00
0	0. 30	2. 38	12. 00	25. 00	0. 90	5. 00	10. 00	45. 00

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1	0.40	0.10	5.00	5.00	0.80	1.00	200.00	45.00	800.00
0	1.70	0.20	5.00	5.00	0.80	1.00	200.00	45.00	800.00
0	2.00	0.20	5.00	5.00	0.80	1.00	200.00	45.00	800.00
0	0.15	0.25	5.00	5.00	0.80	1.00	200.00	45.00	800.00
0	1.60	0.32	5.00	5.00	0.80	1.00	200.00	45.00	800.00
0	2.35	0.68	5.00	5.00	0.80	1.00	150.00	44.00	800.00
0	1.60	0.56	5.00	5.00	0.80	1.00	150.00	45.00	800.00
0	0.55	0.66	5.00	5.00	0.80	1.00	150.00	45.00	800.00
C	0.70	0.60	5.00	5.00	0.80	1.00	150.00	45.00	800.00
1	1.10	0.62	5.00	5.00	0.80	1.00	150.00	45.00	800.00
0	2.15	0.58	5.00	5.00	0.80	1.00	150.00	45.00	800.00
0	0.75	0.60	8.00	7.00	0.70	1.50	150.00	24.00	1000.00
1	0.10	0.75	8.00	7.00	0.70	1.50	150.00	22.00	1000.00
0	0.50	0.83	8.00	7.00	0.70	1.50	150.00	22.00	1000.00
0	0.90	0.88	8.00	7.00	0.70	1.50	150.00	21.00	1000.00
1	1.80	0.18	8.00	7.00	0.70	1.50	200.00	28.00	1000.00
0	0.70	0.23	8.00	7.00	0.70	1.50	200.00	28.00	1000.00
0	0.00	0.25	8.00	7.00	0.70	1.50	200.00	27.00	1000.00
1	0.30	0.25	8.00	7.00	0.70	1.50	200.00	27.00	1000.00

HH52 5 OCT 78

0	4.55	0.10	5.00	5.00	0.80	1.00	60.00	40.00	400.00
1	2.48	0.27	5.00	5.00	0.80	1.00	60.00	41.00	400.00
1	0.20	0.50	5.00	5.00	0.80	1.00	60.00	42.00	400.00
1	2.30	0.63	5.00	5.00	0.80	1.00	60.00	43.00	400.00
0	4.90	0.30	8.00	7.00	0.70	1.00	85.00	33.00	400.00
1	1.10	0.43	8.00	7.00	0.70	1.00	85.00	31.00	400.00
1	0.60	0.56	8.00	7.00	0.70	1.00	85.00	30.00	400.00
1	1.85	0.73	8.00	7.00	0.70	1.00	85.00	29.00	400.00
0	5.40	0.70	8.00	7.00	0.70	1.00	85.00	29.00	400.00
0	5.75	1.13	5.00	5.00	0.80	1.00	85.00	44.00	400.00
0	3.00	1.22	5.00	5.00	0.80	1.00	85.00	44.00	400.00
1	0.80	1.42	5.00	5.00	0.80	1.00	85.00	45.00	400.00
1	2.20	1.48	5.00	5.00	0.80	1.00	85.00	45.00	400.00
0	0.60	1.80	6.00	5.00	0.80	1.00	85.00	45.00	400.00
0	5.20	1.95	6.00	5.00	0.80	1.00	85.00	44.00	400.00
0	2.90	1.85	6.00	5.00	0.80	1.00	85.00	44.00	400.00

APPENDIX C

NATIONAL SAR MANUAL SWEEP WIDTH TABLES

Sweep Width (W) For Visual Search
(W Given In Nautical Miles)

Altitude (feet) / Meteorological Visibility - Nautical Miles	Liferafts 0	Liferafts 5	Liferafts 10	Liferafts 20	Boats (less than 30') 0	Boats (less than 30') 5	Boats (less than 30') 10	Boats (less than 30') 20	Boats (less than 30') 30	Boats (30'-60') 0	Boats (30'-60') 5	Boats (30'-60') 10	Boats (30'-60') 20	Boats (30'-60') 30
1	0.5	0.5	0.5	-	0.5	0.5	0.5	-	-	0.5	0.5	0.5	-	-
3	1.0	1.2	1.2	1.0	2.5	2.4	2.3	1.8	0.4	3.5	3.0	2.7	1.8	0.4
5	1.4	1.6	1.6	2.7	2.7	2.7	2.7	3.2	3.3	4.2	4.2	4.2	4.2	3.3
10	1.8	1.8	2.1	3.6	3.9	4.0	4.2	4.5	5.8	6.5	6.2	6.2	6.2	6.5
15	1.9	1.9	2.6	3.6	5.2	5.3	5.5	6.7	7.0	8.5	8.5	8.4	8.4	8.3
20	2.0	2.1	2.8	3.6	5.3	5.6	6.2	6.8	7.1	8.6	8.8	9.0	9.1	8.9
30	2.2	2.3	2.9	3.6	5.5	6.2	7.0	7.0	7.1	8.7	9.5	10.4	10.1	9.7
40	2.2	2.4	2.9	3.6	5.6	6.3	7.1	7.1	7.2	8.9	10.0	11.0	10.8	10.3
50	2.2	2.4	3.0	3.6	5.7	6.4	7.2	7.2	7.3	9.0	10.0	11.9	11.3	10.7

Altitude (feet) / Meteorological Visibility - Nautical Miles	Boats (60'-90') 0	Boats (60'-90') 5	Boats (60'-90') 10	Boats (60'-90') 20	Boats (60'-90') 30	Small Ships (100-1000 Gross Tons) 0	Small Ships 5	Small Ships 10	Small Ships 20	Small Ships 30
1	1.0	0.5	0.5	-	-	1.0	1.0	1.0	-	-
3	3.9	3.4	3.2	1.8	0.4	4.2	3.8	3.2	1.8	0.4
5	5.0	5.0	4.9	4.7	3.3	7.1	6.7	6.2	4.9	3.3
10	8.0	8.0	7.9	7.7	7.2	11.0	10.0	9.8	8.6	7.2
15	11.0	9.9	9.6	9.1	8.5	13.4	12.7	12.0	10.5	9.1
20	12.0	11.0	10.6	10.0	9.3	15.0	14.3	13.5	11.9	10.4
30	12.5	12.5	12.1	11.3	10.5	17.0	16.5	15.7	13.9	12.2
40	13.0	13.0	13.2	12.2	11.3	17.0	17.0	17.2	15.3	13.5
50	13.5	13.5	14.0	13.0	11.9	20.0	19.3	18.4	16.4	14.5

Altitude (feet) / Meteorological Visibility - Nautical Miles	Medium Ships (1000-10,000 Gross Tons) 0	Medium Ships 5	Medium Ships 10	Medium Ships 20	Medium Ships 30	Large Ships (Over 10,000 Gross Tons) 0	Large Ships 5	Large Ships 10	Large Ships 20	Large Ships 30
1	1.0	1.0	1.0	-	-	1.0	1.0	1.0	-	-
3	4.6	4.0	3.3	1.8	0.4	4.7	4.0	3.3	1.8	0.4
5	8.0	7.0	6.2	4.9	3.3	8.0	7.0	6.6	4.9	3.3
10	11.0	10.6	10.2	9.0	7.2	11.0	10.6	10.2	9.1	7.2
15	14.0	13.7	13.3	11.4	9.4	14.0	13.9	13.7	11.6	9.5
20	15.0	15.0	15.1	13.0	10.9	15.0	15.0	15.6	13.3	11.1
30	17.0	17.0	17.0	15.4	13.1	17.0	17.0	17.0	15.8	13.4
40	17.0	17.0	18.0	17.1	14.7	17.0	17.0	18.0	17.5	15.0
50	20.0	21.0	20.8	18.3	15.9	20.0	21.0	21.0	18.9	16.5

Figure 8-67a

WHITECAP CORRECTION FACTOR (f_w)

WIND (kts)	0	10	15	20	25	30	40	50	60
Rafts	0.8	1.0	0.9	0.7	0.5	0.2	0.1	-	-
Boats	0.9	1.0	1.1	1.0	0.9	0.7	0.2	-	-
Ships	1.1	1.0	1.0	0.9	0.8	0.7	0.5	0.2	-
Dye Marker	0.9	1.0	1.0	0.9	0.6	0.4	0.2	-	-
Smoke	0.8	1.0	0.8	0.6	0.4	0.2	0.1	-	-

Figure 8-67b

LIGHTING CORRECTION FACTOR (f_l)

Percent Cloud Cover	0	10	20	30	40	50	60	70	80	90	100
Cloud Cover Factor	1.1	1.1	1.1	1.0	1.0	1.0	1.0	0.9	0.9	0.8	0.7

Figure 8-67c

FIGURE 8-67

APPENDIX D

METRIC CONVERSION FACTORS

1. Feet to Meters

1 foot = 0.3048 meters

Thus:

3 to 4 foot swells ≈ 1 meter swells,
a 16 foot boat ≈ a 5 meter boat, and
an altitude of 500 feet ≈ a 150 meter altitude.

2. Nautical Miles to Kilometers

1 nautical mile (nm) = 1.852 kilometers (Km)
Thus:

10 nm visibility ≈ 18.5 Km visibility, and
a 2 nm range ≈ 3.7 Km range.

3. Knots to Meters/second and Kilometers per Hour

1 knot = 0.5144 meters per second
1 knot = 1.852 Kilometers per hour
Thus:

a 10 Knot wind speed ≈ 5 meter per second wind speed,
and a 10 Knot search speed ≈ 18 Kilometer per hour search speed.